THE

JOURNAL OF GAS LIGHTING,

WATER SUPPLY, & SANITARY IMPROVEMENT.

[REGISTERED AS A NEWSPAPER.]

VOL. XXX. No. 739.] LONDON, JULY 10, 1877. [29TH YEAR.] Price 6d.

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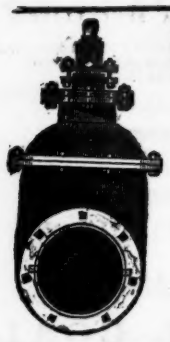
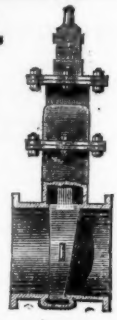


C. & W. WALKERS' DOUBLE-FACED GAS-VALVES.



These solidly constructed double-faced Gas-Valves have taken the place of the old system of the light, single-faced disc, which is too uncertain and unreliable in large bores.

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The Valve is a rigid wedge of solid cast iron, having two perfectly scraped surfaced facings fitting between the two on the body, which are also surfaced.

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The front facing is vertical; the back facing forms the wedge.

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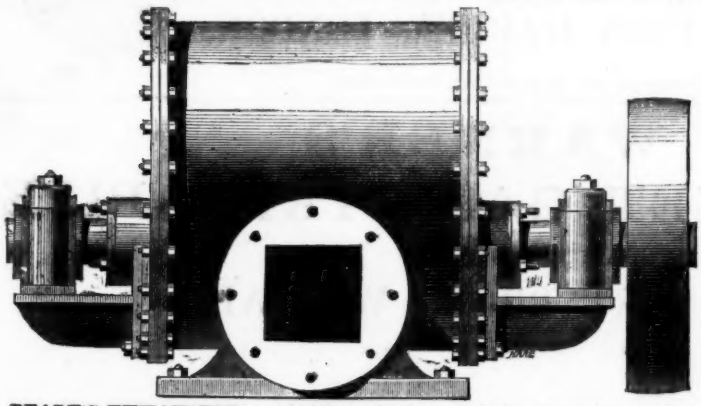

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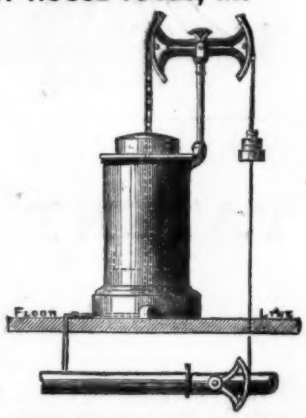
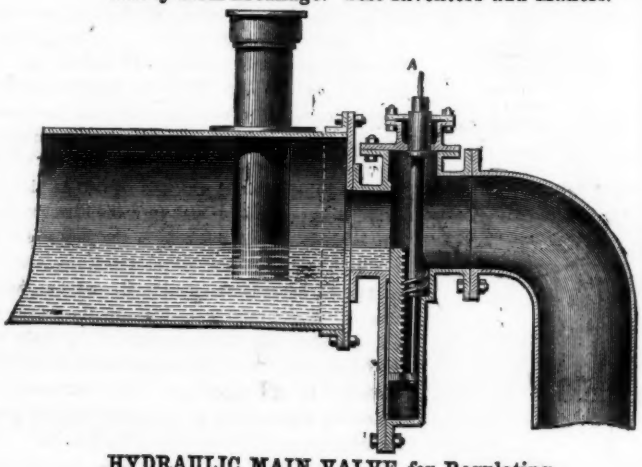


HYDRAULIC REGULATOR.



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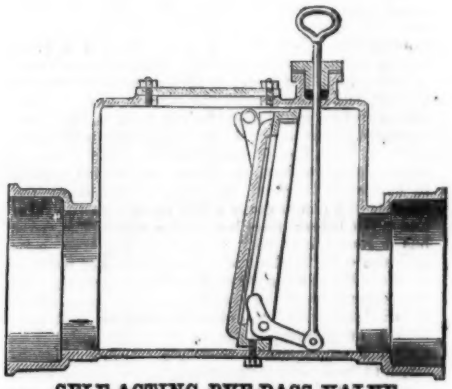

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The apparatus consists of a vertical pipe, the lower end of which is fixed to the main or collar, and the upper end to a box like a common syphon-box. Into this box is fastened a plate having a plug or valve thereon. The valve or barrel is fitted to a fixed seat or plug capable of turning upon it, and is square on the outside, and of such size as to fit a collar made to slip over it, the joint between the collar and the plug being made gas-tight by the former being forced down upon an india-rubber washer, by certain projections coming in contact with other projections formed in the interior of a cap or cover which surrounds the valve and collar before described. The top of the cover has a round hole with a notch or key-way on its opposite sides to admit of the projections or feathers on the collar passing through and on to the plug. To the collar is fixed the stand or service pipe, which is provided with an ordinary stopcock and gas-burner or pressure-gauge at its upper end. The action of the apparatus is simple. When it is desired to make the attachment, a service or stand pipe furnished with a collar, as described, is thrust down through the cap or cover, and, on being turned, will fix or jam itself tightly, so as to remain firmly upright, and at the same time turn on the gas from the main beneath. The action of removing the pipe effectually shuts off the gas, thereby ensuring great security against fraud, and loss by leakage.

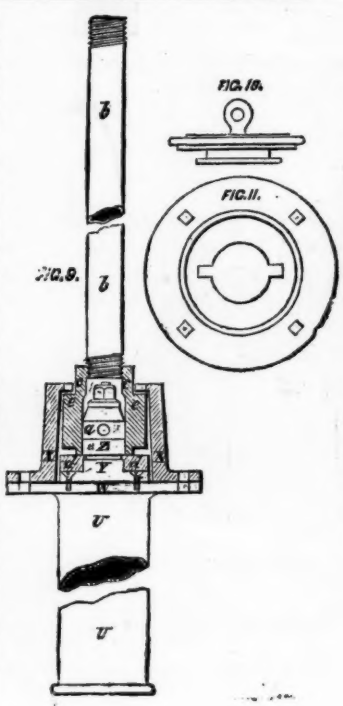

Fig. 9 represents the arrangement for the attachment of removable market or other gas stand-pipes. The view is a side elevation and part section. To the top of the service, U, is fixed a plate, W, and upon that is fastened by bolts the case or box, X. To the plate, W, is also fixed, by screws, the plug or valve, Y, and upon this plug the barrel Z is free to turn. That part of the barrel marked *a* is square. The stand-pipe, *b*, has attached to its lower end the collar, *c*, which is square in the interior, so as to slip over and turn the barrel by the square part, *a*, until the hole in the plug and that in the barrel coincide, when a gas-way will be established between the service, U, and the stand-pipe, *b*. A gas-tight joint between the collar, *c*, and the plate of the plug or valve, Y, is made by the former being forced down upon an india-rubber washer, *d*, by the upper part of the feathers, *e*, of the collar, *c*, coming in contact with inclined projections cast on the inner side of the box, X.

Fig. 10 is a plan of the top of the box or case containing the valve.

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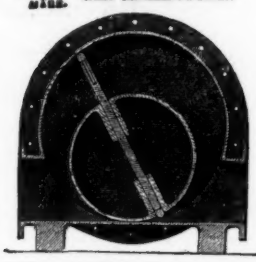

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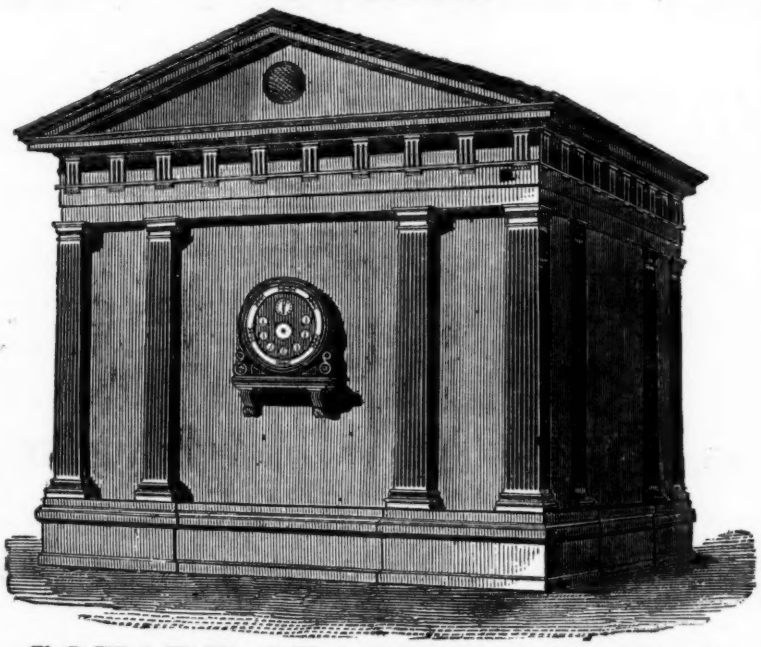

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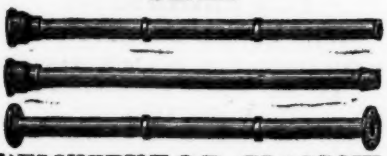
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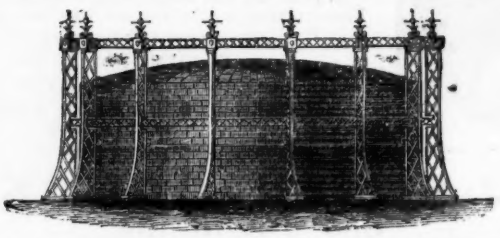
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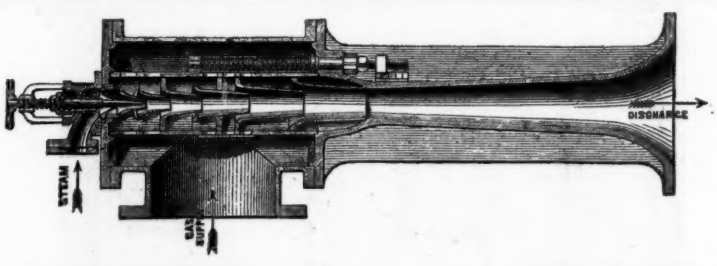

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CLELAND'S PATENT CONDENSER AND STEAM SCRUBBER.
FOR PARTICULARS, APPLY TO
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GERALD J. TUPP, 8, John Street, Adelphi, W.C.,
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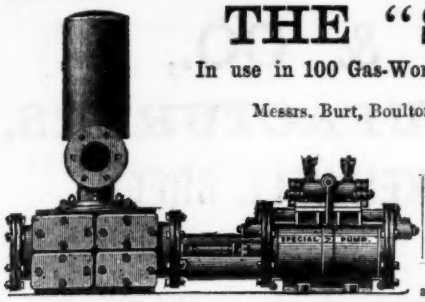
THE "SPECIAL" STEAM-PUMP.

In use in 100 Gas-Works in the United Kingdom for Pumping Ammoniacal Liquor, Water, or Tar.



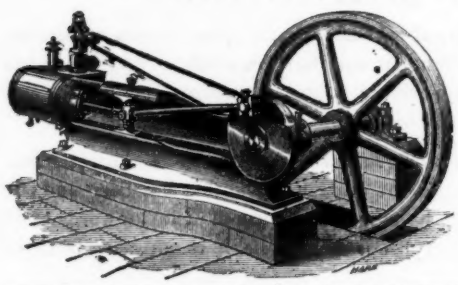
Messrs. Burt, Boulton, and Haywood, Manufacturing Chemists, have FORTY "Special" Steam-Pumps in use at their several large Tar-Works.

200 Sizes made. The following are the Leading Sizes for Gas-Works:—

Steam Cylinder . . .in.	3	4	3	5*	5*	4	6*	5	7*	6	8*	7	10*
Water Cylinder . . .in.	1½	2	3	2¼	3	4	4	5	5	6	6	7	7
Gallons per hour . . .	450	815	1830	1250	1830	3250	3250	5070	5070	7330	7330	9750	9750
Price	£16	£18	£18	£21	£22½	£25	£30	£32½	£40	£40	£50	£50	£65

* These Sizes being usually selected for pumping Tar and Liquor, are always in stock, or nearly ready, fitted with all pump details in iron, and extra length distance-piece between steam and pump cylinder, at a small extra cost.

TANGYE'S HORIZONTAL HIGH-PRESSURE STEAM-ENGINES.



THE DESIGN,
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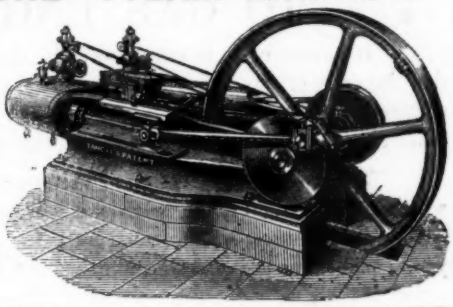
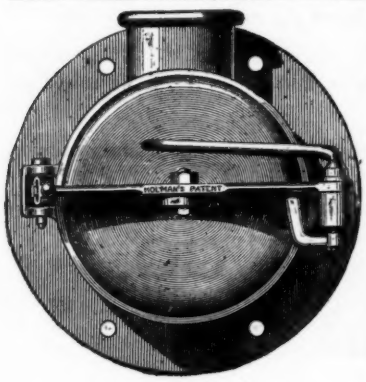
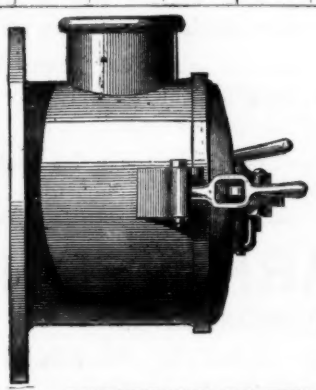
LOW PRICE
OF THESE ENGINES
HAVE CALLED FORTH
UNIVERSAL APPROVAL.

Over 2000 Sold
Since December, 1869.



SIZE	B	C	D	E	G	H	I	J	K	M
Nominal Horse Power	TWO	THREE	FOUR	SIX	EIGHT	TEN	TWELVE	FOURTEEN	EIGHTEEN	TWENTY-FIVE
Price of Engine, with Governor	£28 0	£38 0	£46 0	£70 0	£90 0	£115 0	£127 0	£140 0	£195 0	£220 0
Feed-Pump, extra.	3 0	3 15	4 0	5 10	6 0	7 10	7 10	8 0	10 0	15 0
Variable Expansion Gear, extra	..	..	..	..	13 0	14 0	15 0	15 0	20 0	25 0





MORTON'S
Patent Self-Sealing
RETORT LIDS,

WITH

HOLMAN'S NEW PATENT BRACKETED CROSS-BARS, ANTI-FRICTION CATCHES, AND ECCENTRIC FASTENINGS.

Instantaneous Sealing effected. No Luting. No Duplicate Lids required. Holman's New Self-Sustaining Cross-Bar ensures freedom of joint, and maintains parallel position of the Lids.

Since their introduction in 1869, these Patent Retort-Lids have been thoroughly tested (rigid cast iron is now successfully employed), nearly 25,000 being in use at various Gas-Works in London and the Provinces.

IMPORTANT TESTIMONIAL.

The Gaslight and Coke Company (commonly called the Chartered Gas Company), Beckton, North Woolwich.

Gentlemen,—In answer to your inquiry respecting the Self-Sealing Lids, I beg to say that they continue to work well, and I have every reason to be satisfied with them. I should be very sorry to return to the old system of Luting, and our stokers here freely acknowledge the benefit to them of the new system.

I am, yours truly, (Signed) G. C. TREWBY.

HUNT'S PATENT EQUILIBRIUM GAS-GOVERNOR.

In this Governor a Throttle-Valve is substituted for the ordinary suspended Cone, all external communications being avoided by placing the Lever or Radius Arm (shown in the drawing) inside the Valve-Chamber upon the Disc. The Disc is carried upon steel centres, upon which it is accurately balanced and turns freely. The friction in working is thereby reduced to a minimum. This Governor is extremely sensitive to alterations of inlet or outlet pressure, and renders a large actuating holder unnecessary.

The principal advantages of this arrangement over the ordinary form of Governor are as follows:—

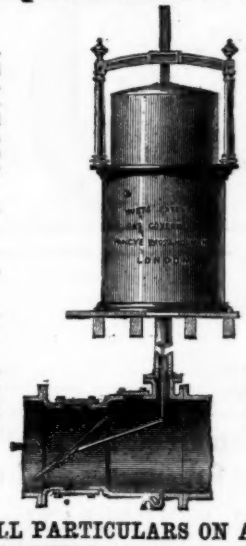
Its sensitive action prevents oscillation.

It is self-adjusting—*i.e.*, it maintains a steady pressure under variations of inlet pressure or a fluctuating consumption.

The inlet to Gasholder being contracted to the smallest possible dimensions, all danger from leakage through insufficiency of seal, tilting, &c., is entirely avoided.

The valve portion being separate from the holder, it can be handled and fixed like an ordinary Slide-Valve direct in the main; and the holder can be placed at any convenient distance immediately above it. The cost is thus materially reduced, and the inconvenience of heavy lifts done away with.

There are no working parts likely to get out of order.



These Governors have been adopted by many leading Gas Companies, among whom are the following:—

The Gaslight and Coke Co. (9), The London Gas Co. (3), and at Abergavenny, Arundel, Birmingham, Cannes (France), Devonport, Dronfield, Dursley, Exeter, Guernsey, Mentone (France), Monmouth, Newcastle-on-Tyne, Oxford, Plymouth, Rochdale, Windsor, &c.

TESTIMONIAL.

The Gaslight and Coke Company,
9, Water Street, New Bridge Street,
Blackfriars, E.C., Feb. 27, 1875

MESSRS. TANGYE BROTHERS AND HOLMAN.

Gentlemen,—The two 24-inch and three 36-inch Hunt's Equilibrium Governors supplied by you, and fixed in the valve-rooms at Whitechapel, Goswell Road, and Blackfriars, are working very satisfactorily.

Yours truly,

(Signed) JOHN JOHNSON.

PRICES AND FULL PARTICULARS ON APPLICATION TO

TANGYE BROTHERS & HOLMAN,

SOLE MANUFACTURERS,

LAURENCE POUNTNEY LANE, LONDON, E.C.

THOMAS GLOVER & CO.,

DRY GAS-METER MANUFACTURERS,

214 TO 222, ST. JOHN STREET, CLERKENWELL GREEN,

LONDON, E.C.

TO GAS ENGINEERS AND MANAGERS.

It having come to our knowledge that a report is in circulation, spread by some unprincipled person or persons, that the cases of our larger-sized Meters are made of Galvanized Iron, we think it only fair to ourselves, and just to our customers, to say, that we never have used, in making any of our Meters, a single pound of *Galvanized Iron*, or any other *cheap* and *inferior material*, and this can be easily seen by opening any of them.

The cases of our large-sized Meters, from 20 lights and upwards, are all made of the very *Best Best Patent Alloy*, which is nearly double the price, and will last more than double the time, of some other material that has been and still is very largely used for the same purpose. And our experience, acquired by an extensive use of it for upwards of 30 years, enables us to say with confidence that no other metal in use for the purpose is so little liable to corrosion from the action of the gas.

We have now in use a Meter made in 1848, and therefore 29 years old, the case of which is made of Patent Alloy; the Meter is still in perfect order, and shows no signs of decay.

The utmost care is exercised by us in selecting none but the very best materials for all parts of our Meters; much of it is made *expressly for us*, as it is not possible to obtain it in the open market of the same superior quality.

The great fall in the price of all materials used in making our Meters has enabled us to give an increased discount, thus giving our customers the benefit of the fall. This we were bound in fairness to do, as we raised the price of our Meters four years ago, when the price of all metals went up.

It will be our constant endeavour, by using none but the best materials, and employing the most skilful workmen, to maintain the high character our Meter has hitherto borne.

WILLIAM PARKINSON & CO.

(ESTABLISHED 1816)

ARE THE ONLY MAKERS

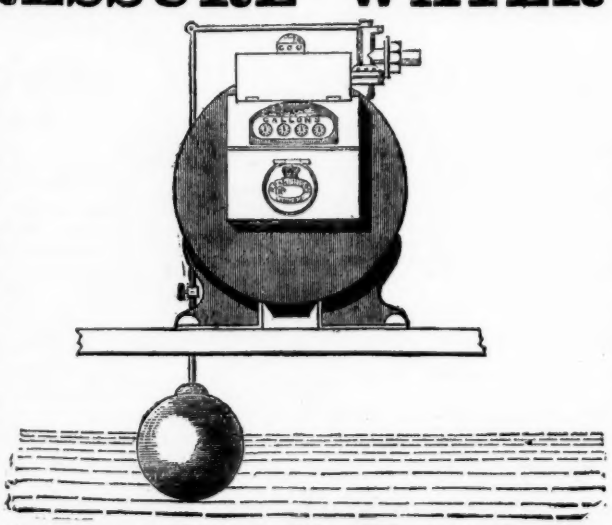
OF THE

LOW-PRESSURE WATER-METER.

These Meters will register with perfect accuracy, either at full speed, or with a few drops only passing through them.

They must be placed over the cistern to be supplied, and the water, after being measured, will fall from the outlet into the cistern below. Each Meter is fitted with a ball-valve, so made that it can be adjusted to shut off the supply at the inlet when the water reaches any required height in the cistern.

The 100-gallon Meter is fitted with a cistern holding about three or four gallons, and may be fixed inside a house, free from the effects of frost, and requires no attention after once being fixed.



From "The Engineer," April 6, 1877.

"Low-pressure Meters have been found to register with almost perfect accuracy, or, at all events, within 5 per cent. either for or against the consumer, and from the nature of their construction are by no means easily deranged. Still, even the low-pressure meters have their disadvantages, but these are chiefly as respects the question of first cost, seeing that they must have a cistern fixed at a higher level than that at which the supply is needed. All things considered, however, the balance of opinion rules at present in favour of the low-pressure Meter, and they are consequently increasing in favour as time goes on."

These Meters have been manufactured by W. P. & Co. for more than 25 years, and are largely used by the following and other Water Companies:—

NOTTINGHAM, DERBY, LEICESTER, SUNDERLAND, GREAT YARMOUTH, SHEFFIELD, NORWICH, LOWESTOFT, COVENTRY, SOUTHEND.

COTTAGE LANE, CITY ROAD, LONDON, E.C.

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THE JOURNAL OF GAS LIGHTING,

WATER SUPPLY, & SANITARY IMPROVEMENT.

TUESDAY, JULY 10, 1877.

Circular to Gas Companies.

WE are indebted to Mr. Versmann for the translation of a letter of considerable interest, at the present moment, from the pen of Dr. Schilling, the editor of our valued contemporary, the *Journal für Gasbeleuchtung*, &c. The communication which introduces this letter we would, for our own part, rather say nothing about, but we expect that English *expert* witness will strongly resent the somewhat offensive imputations thrown upon their honour. We include witnesses on both sides, for each may be said to be equally attacked. "There is always something to be said on both "sides," said one of the most eminent of living *expert* witnesses to us not long since, "and I always take the case first brought "to me." We do not consider him blameworthy. From an abstract and purely moral point of view, it might be argued that "truth" is the only consideration. But "what is truth," even on the vexed sulphur question? Surely, men of more or less eminence may be allowed a difference of opinion without being accused of "prostituting science." We may, however, safely leave *experts*, whatever side they may take, to defend themselves, and pass on to the historical part of Mr. Versmann's letter and Dr. Schilling's communication. It is quite true that on the Continent, in general, the sulphur question attracts no attention. It is, for the most part, altogether ignored. Even at Crefeld, where, it may be said, the industries of Coventry, Derby, and Macclesfield are concentrated, the silk manufacturers make no remonstrance, and we hear of none from the centres of industry above mentioned. Clearly, then, there can be no good cause of complaint.

That sulphur in gas is for the most part a "bugbear" we all very well know, but we have to take matters as they stand, and we find to-day, as we did years ago, that a considerable and influential section of the community, including men of science of some authority, regard sulphur as a noxious ingredient in gas. What, then, are purveyors of gas to do? They may tell the public that they are deceived and deluded, but they will not be believed. We have to convince the gas consumer on two points—first, that the presence of sulphur in gas is not injurious; and, next, that its abstraction involves a nuisance and an expense which produce no commensurate benefit. These things must be taken together. It is idle to deny that sulphur cannot be removed; but is the game worth the candle? We say emphatically not! And, until it is more clearly proved that sulphur is injurious, and until more efficient and inoffensive means for its removal than any now in operation are devised, we must continue to insist on the necessity for a relaxation of the restrictions now imposed by the Metropolitan Gas Referees. We do not wish to see a renewal of the recent expensive strife in the next session of Parliament. The machinery at present in force we believe to be perfectly competent to deal with the matter, and, perhaps, the facts which our correspondent brings forward will prove to the public that their fears of the effects of sulphur are altogether unfounded, and justify the abolition of all limits on its amount in gas.

Mr. C. Woodall's paper on "Some Experiments upon Power "and Fuel Expended on Exhausting Gas" is a practical paper for practical men, which gives no occasion for comment. Too much praise could not be bestowed on the author for the pains he has taken in working out his results so as to put them in the most intelligible shape. The paper will form a most useful guide to managers in making their choice of an engine.

We have always entertained a high opinion of Mr. West's system of gas-making and his stoking machinery, and our view is strongly supported by the experience of Mr. Eldridge, as detailed to the associated Gas Managers. It seems to be made clear that by light short charges of small coal, distilled at high heats, more gas, and of a better illuminating quality, is obtained than by the ordinary plan of working. Mr. West's stoking machinery speaks for itself to any one who has seen it in operation. It is one of the simplest labour-saving machines in existence, and we are not surprised to learn that stokers, although, as labourers, they cannot be expected to regard machinery with favour, are much in love with it. For works of the capacity of those at Richmond and Maidstone, the machinery is eminently well adapted. The "system," to make a necessary distinction, might, we believe, be adopted with advantage in every gas-works. One recommendaion claimed by Mr. West for his system is a large reduction in the amount of sulphur products, and as we have much more to learn regarding the conditions under which these ingredients in gas are formed, we may agree that with light and short charges the probabilities are against a large formation of bisulphide of carbon. Mr. West ordinarily, we believe, keeps his "sulphur" down to about fifteen grains per hundred cubic feet, but it sometimes reaches double that amount. The reason for this—whether it lies in the coal, in the retort, or in the purifier—has not yet been discovered; but, as we have said, thirty grains of sulphur is by no means an excessive quantity, and the most fastidious could hardly object to it.

"A Bored Inspector" seems to make it a charge against the Gas Managers that they did not, at their late meeting, occupy themselves with a discussion on naphthaline—a substance which causes him much worry and trouble. It is not that Managers are not themselves worried by the same material that it was not brought under the notice of the meeting. Probably the "demon" causes more mental anxiety to a Manager than to the most bored outdoor Inspector. Although much has been written and spoken on the subject of naphthaline—its formation and the causes of its deposition—it is probable that we have still something to learn respecting it. We can hardly be said to know the precise conditions under which it is produced. We are not certain whether it is directly formed, or whether it results from the decomposition or dissociation of other hydrocarbons. There can be little doubt that high heats and long charges have something to do with its production, and Mr. West

claims to avoid its formation—at all events to a great extent—by the use of light and short charges. Then, again, it may be asked whether we have, in general, adopted the most effectual means of removing it from gas before it can cause inconvenience in service-pipes. We have always thought that Pelouze and Audouin's Condenser was a form of apparatus admirably adapted for the removal of naphthaline, but this instrument has never obtained much favour in this country. While waiting, however, for the means of removing the "demon," we may consider the best mode of keeping him in submission. Naphthaline is undoubtedly a valuable illuminating agent if its vapour can be got to the burner, and we know that it is kept in a state of gaseous solution by the presence of the vapours of condensable liquid hydrocarbons, such as benzole. One object, then, of the gas maker should be to produce and retain in the gas as much of these bodies as is possible. M. Berthelot appears to have been repeating experiments of which we gave some account last year, and confirms the statement he then made, that the greater part of the illuminating power of Paris gas is conferred by the vapour of benzole, which he finds to constitute three per cent. of the volume of the gas. Naphthaline, we believe, causes no trouble in the French capital, and this may be the explanation. And here we may once more refer to the Körting-Cleland Exhauster, which is also said to prevent annoyance by naphthaline, the explanation of which, if it be a fact, is no doubt to be found in the statement made by Mr. Paterson, that a partial distillation of the tar takes place, resulting, of course, in the addition of vapour of benzole to the gas.

The York United Gas Company have reduced the price of gas from 3s. to 2s. 6d. per 1000 feet. We may mention, also, that the Company are making praiseworthy and, indeed, successful efforts to extend the use of coke as domestic fuel, and the employment of gas lime as manure. The economy of the use of coke is an undoubted fact, and as the profits of a Gas Company largely depend on its sale, no means of promoting this object should be neglected. The York Company give publicity to statements by persons who have used it many years. Prejudices have to be overcome, and opposition on the part of the coal dealers has to be encountered; but in York the more general employment of coke makes progress. So with gas lime as manure. Used intelligently, as the Company say, its effects will fairly compare with those of the more expensive fertilizers. It is said to be especially beneficial to oats and turnips, and we should not be surprised if it do not turn out the best material for preventing the ravages of the Colorado beetle, when that dreaded pest finds its way to this country. We certainly are astonished to learn that the Gas Company obtain five shillings per ton for their lime—a material which, as too many of our readers know, is often only removed from gas-works as a favour.

Mr. Hartley's letter was not without its effect. It evidently induced the Gas Committee of the Middleton Commissioners to give their excellent manager, Mr. Graham, seven days leave of absence to attend the Bristol Meeting, with a *douceur* of £10 towards the payment of his expenses. They might have guessed what would follow. At the last meeting of the Commissioners, a severe attack was made on the Gas Committee for their liberality. One amiable member remarked that they had a Gas Engineer second to none in the kingdom, and he did not see what he could gain by attending a meeting of his brother managers. It is of no use to argue with men of this class, who too often predominate in Local Authorities. Mr. Graham will, no doubt, admit that he acquired valuable information at Bristol, which may at any time be available in the interest of his employers.

We are given to understand that a Provisional Agreement has been entered into between the United General Gas Company and the Corporation of Limerick, for the sale of the undertaking of the former to the latter. In consequence of this, the opposition to the Bill promoted by the Company is withdrawn, on the understanding that the Corporation will next session promote a Bill to sanction the transfer. The consideration to be paid for the works is not yet settled. The Company will carry on the undertaking up to the end of the current year for their own profit, and afterwards as trustees for the Corporation, until the transfer takes places. When that happens, the United General Gas Company disappear.

The Corporation of Stafford are anxious to acquire the undertaking of the Stafford Gas Company, and they have power, under the Act they obtained last year, to effect the purchase; but the price they have offered to the Company is deemed by the Directors so inadequate that they refuse to lay the proposal before their shareholders. The Board, however, express their willingness to continue negotiations with a view to arrange proper and reasonable terms.

Dr. Cross, the Chairman of the Special Gas Committee of the Corporation of Liverpool, is still sanguine that the undertaking of the United Company can be acquired with enormous advantages to the town. He states that he has compiled facts and figures which conclusively prove this, but for a time these facts and figures are kept secret. It is, however, his intention to lay them before the Town Council at their next monthly meeting, when he will move that it be referred to the Gas and Finance Committees to negotiate with the Company for the transfer of their interest. In the meantime, the Council have taken a perfectly unnecessary step, in engaging the services of a Dublin analyst to report on the quality of the gas supplied by the Company, which we know is invariably superior to the statutory requirements.

It will be seen by our advertising columns that Mr. Field's "Analysis of the Accounts of the Metropolitan Gas Companies" for 1876 is now ready, and will be published in a few days. The usefulness of this compilation is acknowledged by every one who has to study the accounts of the Companies.

We publish in another column an interesting communication from our correspondent, Mr. Conrad Voss, of Dessau. It is, however, proper to remark that a similar setting to the one described by him, with a double regenerative furnace, has been invented by Messrs. Lencauchez, Gaillard, and Co., and is figured in the last number of the *Journal de l'Eclairage au Gaz*. It is said to have been in use for some years at the Vaugirard and St. Mandé works of the Paris Gas Company, and to have been recently set up at the gas-works at Béziers. A great economy is claimed for this system. We express no opinion as to who is the person to whom the merit of the invention is due, but we think it right to call the attention of our readers to the close similarity, and probable identity, of the two systems. The yearly saving claimed by the French inventors for a setting of eight retorts on this principle, as compared with the same number worked under the ordinary system, is as follows:—

Saving of fuel	2545 francs.
Saving of labour	800 ,,
Saving by increased production .	1150 ,,
Saving by higher value of coke .	325 ,,
Total annual saving .	4820 francs.

Or about £193.

We have received so late, that it is impossible to publish it in our present issue, the Quarterly Report of Professor Williamson, F.R.S., the Chief Gas Examiner for the Metropolis. It shows, as will be seen next week, that the Metropolitan Gas Companies who are under the supervision of the Chief Gas Examiner continue to comply, and more than comply, with the requirements of their Acts of Parliament and the Instructions of the Gas Referees. Setting aside one or two occasions, when exceptional conditions must have prevailed, the illuminating power of the gas supplied by every company has considerably exceeded the parliamentary standard. As regards sulphur, it will be seen that, with few exceptions, the limit prescribed by the Referees has seldom been exceeded. Altogether, as we have said before, it must be admitted that the Gas Companies in London, who are under the most stringent regulations, faithfully fulfil all their obligations.

The share lists in the monetary articles of the daily papers show that the value of metropolitan gas property has undergone a somewhat serious depreciation. The causes for this we shall not at present particularly inquire into, but we may say that a general opinion is entertained in the City that the prices recently obtaining have been somewhat in advance of their real value. Our readers must not suppose the "Electric candle" has had the smallest influence in bringing about this reduction of price. So far as we are able to make out, on diligent inquiry, the prices which have lately been quoted are generally considered to bring too little profit to investors, and a fall has been looked for as certain to take place. A section of speculators in the City are desirous of seeing 10 per cent. gas stock or shares fall to 150, which, for buyers, would be an enormous gain; but we must caution our readers, who are content with moderate interest and a safe investment, against parting with a single share under the present temporary depression. There is no more secure investment to be had at the present day than is to be found in the shares of the Metropolitan Gas Companies.

FOULIS'S HYDRAULIC STOKERS AT BECKTON.—These machines have been put in operation at the above-named works, with several important modifications in their construction, adapting them to the highly favourable arrangements of the retort-houses there. With the general character of this apparatus our readers are already familiar, from the descriptions which have appeared in the JOURNAL. We shall take an early opportunity of describing the modifications now introduced in detail, and of indicating the economical results obtained therefrom.

Water and Sanitary Notes.

It will be seen in another column that the Town Council of Manchester have resolved on promoting a notable scheme for obtaining an additional supply of water for their city and district. Just as at Liverpool, a growing fear has been that the water resources of the Corporation would not suffice many years longer to meet the constantly increasing demands of the community, and the Town Council have long been casting about for a source of additional supply. Our readers will remember the proposal to obtain a joint supply for Liverpool and Manchester from Windermere or Ullswater Lake. Joint operations, however, seldom suit the fancy of Municipal Authorities, who prefer to take independent action. Thus it has happened that the Corporation of Manchester have resolved on providing exclusively for themselves, and have determined on making an attempt to appropriate the charming little piece of water in Cumberland, known as Thirlmere. One, and perhaps the chief, recommendation of this source lies in the fact that the water will travel all the way to Manchester, through about a hundred miles of tunnels and pipes, by gravitation. The first cost of the means of giving ten million gallons per day to Manchester is estimated by Mr. Bateman approximately at £1,700,000, exclusive of the cost of land. The area of the lake will, however, be increased by artificial means, so as to make it capable of supplying fifty million gallons per day. Sentimental objections are, of course, raised, that an embankment would spoil the natural beauty of the scenery, but we do not think that these will have much weight in Parliament. The great obstacle Manchester will have to overcome will be the opposition of the landowners and others who have water privileges in connexion with the lake. The opposition of these, however, we cannot imagine to have any serious effect, and next year we expect to be able to congratulate the Corporation of Manchester on their new acquisition. They have undertaken a grand work, in some respects more important than that undertaken by the Corporation of Glasgow when they resolved on tapping Loch Katrine.

A Committee of the House of Lords have passed the preamble of the Bill to confirm the Provisional Order of the Local Government Board for the formation of a joint Board, with power, or rather under compulsion, to effect the sewerage of the Lower Thames Valley District; but they have excluded Twickenham from the scheme. The United Board will have three years to complete the work, but as they must first decide on the plan, which will, we have little doubt, give rise to long discussions, they may find it difficult to complete their task within the time prescribed. As soon as the Board is constituted—that is, if no successful opposition to the Bill be raised in the Commons—we shall obtain more definite information as regard the plans for the disposal of the sewage which have already been proposed. At present we cannot express an opinion on the three which, we understand, have been suggested.

Correspondence.

[*We do not hold ourselves responsible for the opinions expressed by Correspondents.*]

STEAM-JET EXHAUSTERS.

Sir,—Mr. Paterson's paper on "Steam-Jet Exhausters," read before the British Association of Gas Managers, at their recent meeting, the discussion which followed, and your notice of both, in your "Circular to Gas Companies" of the 26th ult., call for a few remarks.

First, let me put you right by saying that we fix the jet exhausters, and always recommend them to be fixed, at the outlet of an *efficient* primary condenser, and at the inlet of a steam scrubber, the only scrubber used here in connexion with the jet.

I gladly avail myself of this opportunity, as a member of the Association, to thank Mr. Paterson heartily for the time and thought he has evidently devoted to the exhauster, and especially for the ingenious and conclusive manner in which he has corroborated its claim to improvement in the quality of the gas. That improvement Mr. Paterson finds to be three-quarters of a candle on 15 or 16 candle gas—say, 5 per cent.

Six years ago, when I first drew your readers attention to the steam-jet exhauster, I claimed distinct and decided improvement in illuminating power, as the result of upwards of 130 photometric experiments, extending over nine months. The average amount of improvement—about one candle on 21-candle gas—was not then stated, as it was thought desirable to have still further experience before doing so. One candle on 21-candle gas is practically the same as three-quarters of a candle on 15 or 16 candle gas. We may now look on this point as settled—viz., that the use of the jet produces an improvement of at least 5 per cent. But from three years observations of what I shall call "common" gas and "steam" gas, produced from various, but simultaneously from the same materials, and burning continuously in two jet photometers, I am quite disposed to credit those who claim an improvement of two candles.

Into Mr. Paterson's theory of the cause of this improvement I shall enter but slightly. If in his case, with his peculiar arrangements, it arises from the distillation of tar, I agree with Mr. Morton that tar is where it ought not to be. As to the "thick pitchy deposit" in the steam condenser, we know, and have known, nothing of it here, except once or twice, some years since, when the primary condenser was overworked. We are equally free from naphthaline. Mr. Brott's and Mr. Goddard's experience on the latter point may be fairly set against Mr. Paterson's.

Mr. Paterson doubts the permanence of the gain in illuminating power. We know of no loss of this power. Had there been any, we could hardly have failed, in the course of years, to feel it, the steam gas having been repeatedly tested, with identical apparatus and manipulation, at a distance of three miles from the place of production.

As to steadiness of gauge, to my astonishment those cases are excepted where the hydraulic dip is in action. If this exception had been limited to jets fixed at the outlet of the hydraulic main, and constantly influenced by the surging of the water in that main, we should merely reply that if a quite steady gauge is indispensable the exhauster ought not to be fixed there. But in reference to jets fixed anywhere between the outlet of the primary condenser and the gasholder, in works where the hydraulic dip is used, hundreds of gas managers besides the present writer know that the above exception is a delusion. In some cases, however, the governor is allowed to become so clogged with oil and dust, that its want of sensitiveness is not surprising.

I shall here state briefly the conclusions to which seven years experience has led me, and which I have for some time adopted as rough-and-ready rules for daily practice, in carbonizing cannel and coal, chiefly from the Wigan field. Some users will probably find, as I have often found, the differences to be greater than the following, sometimes less:—

First, given the same cannel and coal in the same proportions, and *the same yield per ton*, we shall then have about 5 per cent. greater average illuminating power from "steam" than from "common" gas.

Secondly, given the same materials in the same proportion, and *the same illuminating power*, we may take, with safety, about 400 feet per ton more from our material with the jet than with exhausting machines.

Thirdly, given the same material, *the same illuminating power, and the same yield per ton*, we may then use about 5 to 10 per cent. more coal with the jet than with exhausting machines.

Thus the advantage of the steam-jet, touching illumination, offers itself in three different shapes, and manufacturers can have more light or more gas per ton, or a larger proportion of cheap material.

When I read that "the close personal attention of the man in charge" is requisite, "under any circumstances," to secure a steady exhaust with the steam-jet, I read of a condition which would not be tolerated here for an hour, and which ought not to be tolerated anywhere—a condition which would have strangled the jet exhauster in its birth; for surely any apparatus that requires perpetual coddling is out of place in gas-works. From the first conception of this exhauster, perfect steadiness with the slightest attention was foreseen, and, in the first crude trial made, these features struck every observer. These are, indeed, *necessary* features of the steam-jet *per se*, and where they are not found, there must be something wrong which is capable of being put right.

Only a degree less surprising than the close attention required, is the wholly unprecedented consumption of steam in the Cheltenham jets. If the cause is not the want of adjustment of the sliding cylinder or sleeve, as suggested by Mr. Morton, it may, perhaps, be found in the fracture of some of the nozzles, or in their being clogged by the "pitchy deposit" mentioned. Mr. Paterson examined "the nozzle," and found "it" all right; but there are, I think, seven or more nozzles in each of his 60,000 feet exhausters, the fracture or obstruction of any of which would call for an excess of steam. I cannot give your readers my exact consumption of water, in consequence of the use of the steam for various purposes; but I may observe that the quantity used at Cheltenham—viz., two gallons per 1000 feet of gas, with a back pressure of 12 inches—would so dilute our ammonia water as to render it unsaleable, which would speedily swamp the jet exhauster.

The large amount of cooling surface required in Mr. Paterson's latest arrangements for the condensation of the steam—viz., 190 square feet per 1000 cubic feet of gas per hour—is what might have been expected under the circumstances, and is about 120 per cent. more than we find necessary for cooling only, with similar back pressure.

I greatly regret being compelled to criticize, as I have done, some parts of this elaborate paper; but truth has a right to command, while politeness can only persuade. However, it is the more gratifying to me to conclude by calling special attention to another remarkable corroboration by its author of Linacre experience—viz., that even an excessive washing of gas by steam, *after* the usual cooling, scrubbing, and washing, instead of injuring, improves the quality of the gas. Is the *higher* improvement claimed for the jet by some engineers due to the avoidance of this *superfluous* washing? It also deserves particular remembrance that, maugre all drawbacks, Mr. Paterson means to rely on his jets as his sole means of exhausting.

Other duties permitting, I hope to return to the paper and discussion next week, when I shall have somewhat to say respecting the much slighted steam scrubber, and also anent the "slow speed," or, more exactly, the "scrubbing" condenser, which has been sometimes confounded with its unlucky *confrère*, and even more subjected to the "pooh-pooh" style of criticism. It will also be my duty to point out the saving in purifying expenses, which may be anticipated by the use of these scrubbers and condensers.

Meanwhile, I must content myself with assuring the reader that we are scarcely more satisfied of the simplicity and efficiency of the jet exhauster than of the simplicity and efficiency of the "Linacre method" of condensing, exhausting, and scrubbing. The best proof of this that I can offer is the fact that Mr. King has thought fit, in extensions now in progress here, to extend this method exclusively.

Linacre, Liverpool, July 7, 1877. Wm. Cleland.

MALTA AND MEDITERRANEAN GAS COMPANY.

Sir,—In your excellent report of the general meeting of the above company you represent me as stating the increase of capital in the last seven years at £1700, whereas I stated that the increase of capital during that period had been £17,000. Will you kindly notice this error in your next number, as my remarks, as they are printed, appear absurd.

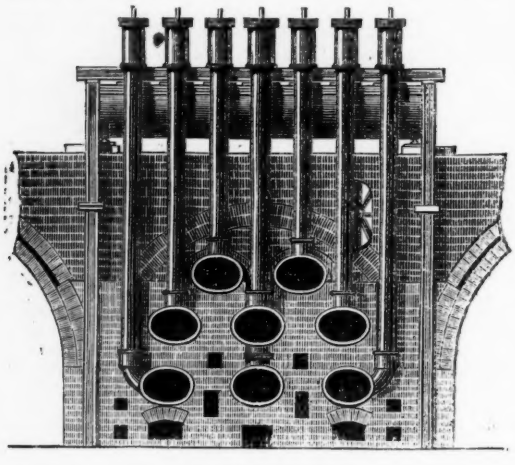
H. P. Stephenson.

OECHELHAUSER'S GENERATOR FURNACES.

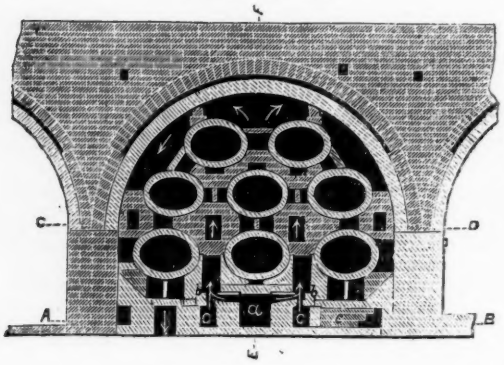
SIR,—In your JOURNAL of the 30th of January last you published an illustrated description which I had had the honour of sending you, of Oechelhäuser's system of settings of six retorts, with some figures of management, production of gas, firing material, &c., and I promised at that time to provide you with a sketch of one of the new Oechelhäuser's generator furnaces. Indeed, there are neither improvements nor inventions in the field of gas-making on the Continent with which the name of Oechelhäuser is not associated, or in which he has not participated in an eminent manner. His efforts and achievements, however, consist chiefly in improvements in retort-settings, and it can justly be said that we now-a-days are chiefly indebted to him for the admirable system of retort-setting we now possess, a fact which is readily acknowledged on all sides.

The various inquiries which have, in consequence of the publication of my letter in your JOURNAL, reached me from all parts of the United Kingdom, as well as from America, concerning this system, show the lively interest which my brother managers, even from the other side of the Channel, take in this matter.

I now, with much pleasure, make good my promise, by sending you the subjoined sketch of the new Oechelhäuser's generator furnaces.



FRONT ELEVATION.



TRANSVERSE SECTION.

The principle of the generator, or gas heating apparatus, as is known, consists in the consumption of the carbon contained in the fuel by its previous formation into carbonic oxide, which is produced in a shaft furnace, or generator, by a deep layer of firing material. The carbonic oxide thus produced is then conducted by means of a flue to the proper hearth of combustion, where, by combination with heated atmospheric air, it is turned into carbonic acid, with evolution of enormous heat.

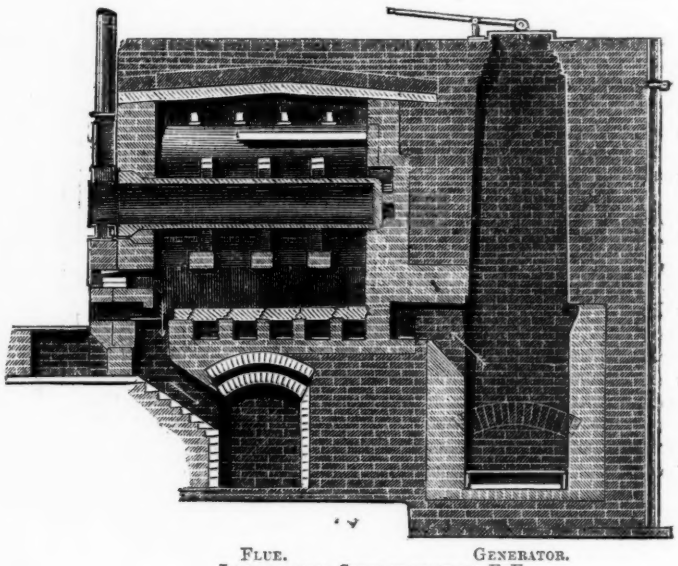
As may be seen from the annexed drawing, the generator furnace contains eight retorts. In place of the grate in the fire-bed, the generator is placed in this case behind the furnaces. However, it can be placed anywhere without disadvantage, even 10 to 15 feet from the furnace, beneath the floor. The filling takes place from above by means of an aperture, constructed so as to be shut by a lid, and in order to exclude the air from above, the lid is merged in a ring of cast iron, filled with sand or water.

The air employed for the combustion of the coke into carbonic oxide enters at the lower end of the shafts, where also the slag formed is run off spontaneously, and needs only to be removed from time to time with a hook.

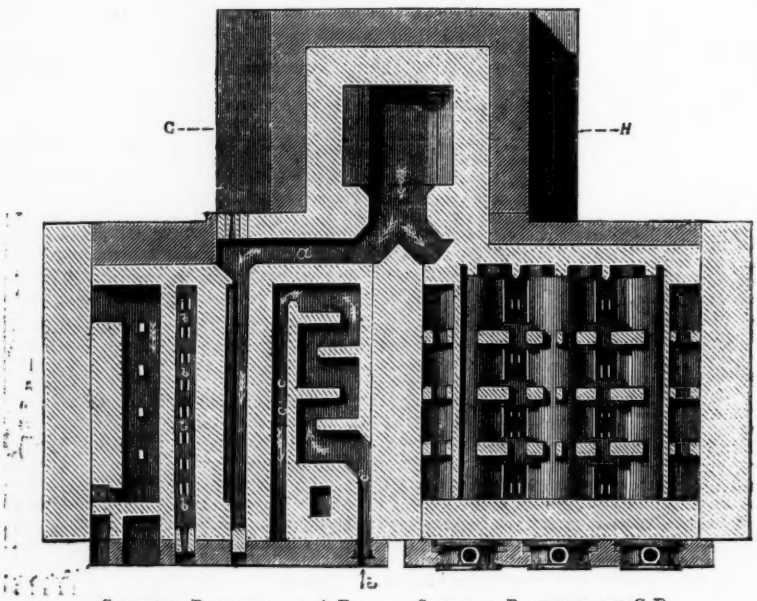
The produced carbonic oxide now enters by a flue, *a*, into the furnace, where it reaches the proper place of combustion by several small apertures, *b b*, which are placed in two rows in the midst of the oven, and extending the whole length of the same. The atmospheric air, now required for converting the carbonic oxide into carbonic acid, after having entered from the front of the stove by the flues, *c c*, and having become heated by passing under the lowest retorts, combines with the carbonic oxide, and causes the most perfect combustion, which is evinced by the evolution of a very high degree of heat.

The regulating of the degree of heat in the furnaces takes place by the moving of the damper at the mouth of the air-flue, by which process air can be let in or shut out, according to requirement.

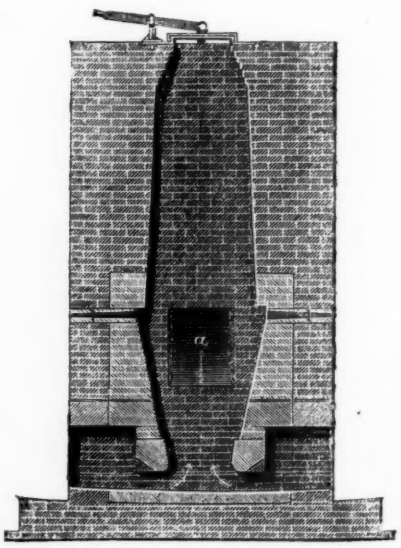
As may be further seen from the drawings, one generator serves for two beds of 8 retorts each, consequently supplies 16 retorts. These are charged every five or six hours, which can be done by any one, even the most inexperienced person, as he has simply to put in fuel. As the German Continental Gas Company introduced this method of firing some time ago, I am in the position of being able to give you some exact figures of management. The average production of gas in 24 hours



FLUE. GENERATOR.
LONGITUDINAL SECTION THROUGH E F.



SECTIONAL PLAN THROUGH A B. SECTIONAL PLAN THROUGH C D.



SECTION THROUGH G H.

from such a setting of eight retorts is 65,000 English cubic feet, and the consumption of fuel for every hundred-weight of coal carbonized is 16 to 17 lbs.

The great advantage of these generator furnaces is obvious, as, besides the great saving of fuel, the production of a greater amount of gas per retort and per day, with less labour in firing; the retorts themselves are in this manner better preserved, having to suffer less by the immediate action of the fire, and also from the effects of dust and clinker.

Over and above this, every existing furnace of the old construction can easily be altered to this method without disturbing the whole fabric.

This Oechelhäuser's generator furnace I can recommend as still more practicable and useful than the common furnaces of six retorts, which I recommended in my last article in No. 716 of this JOURNAL. According to the annual report of the German Continental Gas Company for 1876, more than 50 gas engineers have visited one of their establishments at Dessau in order to study this system, which has gained such a reputation that it is now with us almost exclusively in use.

Those gentlemen who wish to inspect this kind of working may find them the nearest at M. Gladbach, on the Rhine, *viâ* Aachen, which, belonging to the above-mentioned company, is in continual practice. M. Oechelhäuser, the chief director of the company at Dessau, known as well for his amiability as for his scientific knowledge, is sure at all times to afford every facility for visiting these works, and will readily give any information which may be desired.

Krakau in Galicia, June 16, 1877. CONRAD VOSS, Engineer.

MECHANICAL *VERSUS* JET EXHAUSTERS.

SIR,—Messrs. Gwynne's letter, taken in conjunction with Mr. Paterson's paper on the jet exhauster, will enable gas managers to estimate at their proper value the advantages or disadvantages of that apparatus compared with the old mechanical means of drawing the gas from the retorts.

In the first place, I think it somewhat unfair to charge Mr. Paterson with being a partisan in favour of the jet exhauster. I am sure every one present at the reading of the paper must have been struck with the unbiassed manner in which he placed the *pros* and *cons* of his comparison side by side; and when it is remembered that not only was the paper simply a record of an experimental trial, in which the author appeared to avoid everything that might give rise to controversy, but also that each of the objections raised in the letter of Messrs. Gwynne, as well as several others, were fully stated at the meeting, I am at a loss to imagine how even the opponents of the jet exhauster—viz., the manufacturers of the mechanical exhausters—can, with any justice, "wish to point out the fallacy of the arguments used" "to show the economy (?) of the jet exhauster." The author of the paper, it is true, shows his belief in the superiority of the steam-jet by adopting it at his works, but no one reading his paper in the JOURNAL of the 26th ult. can for a moment accuse him of arriving hastily at this determination.

Having seen the apparatus at Cheltenham, I am in a position to state that no exhauster, that I am aware of, works with such a *perfectly stationary level gauge* as this. As stated in the paper, no variation is perceptible, even on a King's gauge, indicating hundredths of an inch; indeed, it is difficult to believe the gauge is really in operation, until a turn of the screw, on the spindle of the exhauster, indicates a pressure or vacuum, as the case may be, of a few hundredths of an inch. If this is not perfect exhaustion, what is?

The large quantity of water required to be converted into steam is, doubtless, a serious drawback, but one that will probably be modified when the jet exhauster has received the amount of attention that has been devoted to the perfection of the old exhausters. The cost, too, of the subsequent condensing plant is one that experience will probably tend to reduce; indeed, this has already been attempted by placing the jet exhauster immediately on the hydraulic main, and making the ordinary condensers perform the whole process of condensation.

But against these and the other defects pointed out by Mr. Paterson, is there nothing to be said in favour of the new apparatus? Water and fuel and prime cost are not the only, or even the paramount, matters to be taken into consideration. If the jet exhauster gives us an increased yield, though only a few hundred feet per ton, does this not compensate for all these disadvantages? If we get, in addition, an increased illuminating power, though only, as Mr. Paterson states, of three-quarters of a candle; if, moreover, the whole thing can be placed in a mere nutshell; if we get the wear and tear reduced to next to nothing; if there is no oiling of bearings, no packing of glands, no friction due to gearing, shafting, &c., no possibility of a break-down by any disarrangement of working parts—surely all these more than outweigh the slight extra cost of water and fuel which, even with the apparatus as at present constructed, is not a serious item of expenditure in a gas-works.

I have not one word to say against the very excellent direct-acting mechanical exhausters constructed by Messrs. Gwynne and Co., though I am unacquainted with their means of ensuring a steady gauge, referred to in the last paragraph of their letter in your last issue; but I do think they should allow some advantages in favour of the still more direct action of the new instrument. At all events, I think Mr. Paterson has done good service in bringing before his professional brethren the experience he has gained in his trial of the Körting-Cleland's Steam-Jet Gas-Exhauster. STEAM-JET.

NAPHTHALINE.

SIR,—I, too, am a man with a grievance, and I claim also, like Mr. Spice, not to be called a "bore."

Why have the British Association of Gas Managers not shown the gas-makers (of London, at any rate) how to prevent the deposit of naphthaline? Again, what do I, or any other inspector, care about the scientific and mysterious subjects of the papers read at Bristol, such as "Experiments on Fuel," "West's System" (who is West?), "Accounts," "Increased Consumption and How Obtainable" (I and another inspector may have a word or two to say about that), &c.? But I do care about the prevention of naphthaline, because every now and then (why not always?) we are overwhelmed by the number of consumers complaints of stopped services, meters, and even fittings, and all caused by this demon naphthaline, throwing all our ordinary business into dire confusion.

I believe there must have been a paper on the subject, and that it has been mislaid by the Association Secretary. I hope he will not be angry, but will send it to you at once, and that you will graciously print it.

As Mr. George Livesey did not read a paper on naphthaline, perhaps we have lost it through his non-attendance; and if so, he has certainly lost a fine opportunity of earning the gratitude of, amongst others,

A BORED INSPECTOR.

AUTOMATIC LAMP LIGHTING.

SIR,—In your "Circular" of this week, you say, referring to my paper on automatic lighting: "But as our apparatus of distribution is perfected, automatic lighting will become more and more possible. To-day it is little more than a dream."

Although, Sir, I cannot help fancying that this sentence carries a waspish sting in its tail, still I am far from objecting to a fair emission of opinion, and my object in writing to you is principally to point out that any local failure of the apparatus for lighting and extinguishing automatically, referred to in my paper, is really a most useful indicator to gas companies that their apparatus of distribution—*i.e.*, main or service pipes—in that particular locality is defective, and I am sure, Sir, you and all intelligent managers of gas-works will agree with me that the sooner such a state of things is remedied the better.

It is in the interests of gas companies, as it is to the comfort of consumers, that a full supply should be given to every one, and surely this is not a time to hold the hand in employing whatever capital is legitimately necessary for that purpose. Upon the whole, therefore, I think you must confess that even a considerable increase in mains is not a really serious matter for most gas companies to contemplate, either in cost or in time of accomplishment, and that although at present only "little more than a dream," the realization need not on that account be further distant than—following the same metaphor—the interval between slumber and waking. A. F. WILSON.

34, *St. George's Road, London, S.E., July* 6, 1877.

DR. WALLACE ON THE AITKEN AND YOUNG PROCESS.

SIR,—Referring to the summary of the report by Dr. Wallace, of Glasgow, on the Aitken and Young process, and the ordinary process of gas-making as conducted at Hamilton, N.B., contained in your issue of the 26th ult., p. 1056, will you allow me to suggest that readers of that summary should read these words, "by the ordinary process," as often as they occur, as though the words, "as conducted in Hamilton Gas-Works," immediately followed?

This suggestion may timeously prevent errors, and allow gas managers to consider whether the ordinary process of gas-making, as in use at Hamilton, is such an arrangement as would meet modern views, or be taken as a sample of works for manufacturing gas according to modern notions of an ordinary process.

I should prefer to have had the full report, instead of a summary and quotations from the report of Dr. Wallace. WILLIAM KEY.

Gas-Works, Tradeston, Glasgow, July 4, 1877.

SULPHUR PURIFICATION.

SIR,—The great gas fight has come to an end, and, as you are publishing the evidence brought forward on both sides, the readers of your JOURNAL will shortly be able to form their own opinions on the value of the whole inquiry. Meanwhile it may be interesting to point out how this London bugbear—this sulphur question—is looked upon abroad, and I therefore beg to send you some statements, which I trust may be acceptable.

Dr. Schilling, the editor of the *Journal für Gasbeleuchtung*, well known also in this country as the first German authority in gas matters, has favoured me with full details, translation of which I enclose, as they prove the sulphur question to be simply unknown in Germany and Austria. Of more than 400 contracts with gas companies, two only refer to bisulphide of carbon—Stuttgart and Vienna. In neither place is the gas tested for this impurity, and moreover, as the Vienna contract, entered into with the Imperial Continental Gas Association, stipulates a limit of 30 grains (not the German *gran*) per 100 English cubic feet, it is evident the English company voluntarily proposed this restriction, the import of which neither they nor the Vienna authorities ever considered, and hence the stipulation has always remained a dead letter. However, Dr. Schilling's communications so fully settle the matter as far as Germany is concerned, that any further remarks of mine would be out of place.

In America, gas is much more extensively used than anywhere else, for domestic cooking and heating, and also for business purposes. Here we find the remarkable fact that, in 1868, a lengthened inquiry took place in New York, similar to the one just concluded before Mr. Plunket's committee, but with the difference that the authorities and the gas company took up exactly reversed positions. The Gaslight and Coke Company prove the lime process must necessarily be a nuisance; they therefore wish to go back to the oxide of iron, and in this they are opposed by the authorities. In New York, on the other hand, the Metropolitan Board of Health, nine years ago, came to the conclusion that the Metropolitan Gas Company did create a nuisance by the lime process, and ordered them to discontinue the same and to adopt the oxide of iron, under threat of closing the works. The readers of your JOURNAL, in referring back to 1869, will find an account of the investigation, in the course of which the most eminent chemists gave evidence on both sides, among others Professor Chandler, for the Board of Health; Professors Silliman and Würtz for the company. The final result was that the company had to adopt the oxide, and the nuisance disappeared.

This opposition on behalf of the company may appear strange, but it must be recollected the oxide process at that time was of recent introduction abroad, and the material itself could not be obtained without difficulty; in fact, the lime was much cheaper. Some of the reasons for pleading delay in the change are highly amusing, and have a refreshing savour of American 'cuteness. The company stated, for instance, they required a number of perforated planks as false bottoms, but there was only one man in New York who could bore the holes, and he was busy boring holes for some one else.

There are, of course, no restrictions as to sulphur compounds in New

York; but it appeared in the inquiry that the gas contained about 45 grains, and the Board of Health distinctly proved by their officers that no complaint had ever been made to them, the proper authority, while the company recited all the old and oft-told stories about injury to books and furniture which were raked up and again paraded the other day with much ingenuity, partly as entirely new discoveries by a younger generation.

But why should the London gas companies alone in the whole world be saddled with these severe restrictions, the necessity and fairness of which are, to say the very least, extremely doubtful? The history of the invention of the pretended injury resulting from burning the sulphur compounds is a very strange tale, but stranger still and most deplorable is the manner in which the settlement of the question at various times has been attempted.

I do not intend to dissect or analyze the recent proceedings—this would be too ungrateful a task; but I may be allowed to say that, in perusing the evidence, one cannot help being struck with two great facts which stand out most conspicuously—namely, the unfitness and inadequacy of the tribunals chosen to decide such matters, and the recklessness which leads chemical, and other so-called scientific or professional, witnesses to jauntily and unconcernedly pour forth the most astonishing assertions as evidence on oath.

Surely in such a case, which depends at least as much upon theoretical and practical considerations as upon matters of fact, the rule should not obtain that whoever has studied a given question the least is best qualified to judge of its merits. We have several members of Parliament especially qualified for such inquiries, and it is deeply to be regretted that not even one of them—Professor Playfair, for instance—had been selected for the committee. Had this been the case, many of the witnesses for the opposition would not have dared, or would not have been allowed to air their little wisdom, and—I cannot help using a strong expression—to degrade and prostitute science.

The members of the committee have filled a very difficult, unenviable position, for the conflicting evidence must have been perplexing and bewildering in the extreme to an impartial mind, the strongest proof of which is the fact that the committee, almost at the last moment, were willing to grant the company 35 or 40 grains, and finally solved the difficulty by declaring the preamble of the Bill not proved.

The whole system is radically wrong, and the conclusions arrived at in this case are based upon mere assertions stated as positive facts. I abstain from referring to the mass of wonderful special chemical evidence brought against the company; even the opposing counsel thought it prudent to touch but lightly upon it—nay, distinctly to put it aside altogether; but I will point out the evidence in reference to Newcastle, Dover, and Nottingham, the three strongholds, the towns which were held up as examples of lime purification without a nuisance, and yet great purity of the gas.

Newcastle has a parliamentary limit of 17 grains; the gas chemist appointed by the town stated the company kept well within this limit, the average for 1876 was 11 grains; and yet, from an official report issued by this very same gentleman, and published in your JOURNAL of the 8th of May, it appears that during the month of April, in eight tests, the sulphur was twice over 19 grains, once 18·54 grains, and once over 30 grains.

The Dover witness, on the 16th of May, boldly stated, without giving any proof whatever, that the gas there and in other places under his control contained about 15 grains, against which assertion I adduce the fact that the Dover gas contained, within a fortnight from that time, from 29 to 35 grains as ascertained by my own personal tests, extended over several days.

Now, as to Nottingham. There the sulphur compounds in the gas are said to be kept down to 15 grains without any difficulty—a statement made not by a chemist, but by an engineer, who first amused the committee with his theories on the formation of bisulphide of carbon, and the action of ammoniacal liquor, which he fancies absorbs enormous quantities of bisulphide, and hence the abominable stink of the liquor, and then finally astonished the chemical world by glibly asserting that *pure lime* takes out the bisulphide, and that this is part of the Nottingham process.

I have selected these three points, because the opposing counsel found it convenient to utilize them to the utmost of his advantage.

The weakness of the whole final argument becomes transparent from the fact that the counsel, in his speech, presented the whole matter as a personal question, a fight between Mr. Evans and the Gas Referees. This speech of a special pleader answered its purpose for the moment; it will be read and forgotten; but meanwhile it is disheartening to realize the amount of intellect brought to bear upon a question which, in a different manner, might have been satisfactorily settled, and which, at present, remains as unsettled as ever before.

FREDERICK VERSMANN.

35, *Whitecross Place, Wilson Street, London, July* 4, 1877.

[ENCLOSURE.]

Translation of a letter dated the 25th of April last, written by Dr. Schilling, Editor of the "Journal für Gasbeleuchtung."

Among the German Imperial Laws are only two which have any reference to gas industry:—

1. *Das Allgemeine Deutsche Handelsgesetzbuch*—the General German Commercial Statute Book, in so far as it regulates the arrangements of public companies and commercial transactions generally.

2. *Die Deutsche Reichs Gewerbe-Ordnung*—the German Imperial Trades Regulations, in so far as it places the works for manufacturing and storing gas among those which require a previous special permission. These regulations say:—"16. Permission by the authorities appointed by the laws of the different countries is required for the erection of all those undertakings which, by their local situation or by the character of the works, may give rise to serious injury, danger, or annoyance to the proprietors or inhabitants of the adjoining lands, or to the public generally." This permission for the erection of a gas-work once given by the authorities, no further supervision takes place by the Government (only the boilers are subject to inspection, as is every single boiler in the country).

In one single instance only the Imperial Trades Regulations may again be enforced; 51 says:—"The further working of any undertaking may be stopped by the authorities in consequence of excessive injury or danger to the community; but the proprietors have to be indemnified for any loss they can prove."

The control of the quality of the gas—*i.e.*, its purity and illuminating power—is left by the Government to the communal authorities, who either own the gas-works themselves, or enter into contracts with private parties. Wherever the works belong to the community, the control is voluntary; when they are private property, the contracts contain restrictions. These gas contracts in Germany are mostly made on the basis that the gas-works acquire for a certain number of years the exclusive right of utilizing the public streets and places to lay down their pipes, and the contractor of the company undertakes to erect the works and to supply the gas required. The illuminating power, purity, price, &c., often also the pressure, are subject to special arrangements, which form part of the contract.

In Hamburg the gas-works belong to the state, and are leased out for 10 years. The contract contains the following clauses as to purity—viz., "23. The lessee is bound to supply everywhere, and at all times, gas which is absolutely free from sulphuretted hydrogen; even after prolonged contact of the gas with acetate of lead, no reaction must take place. The gas must be so far free from ammonia that only traces can be detected. 24. If sulphuretted hydrogen should be found in the gas, the lessee in every single instance is liable to a fine of £75."

In Munich, the gas-works belong to a company, and their contract with the magistrates stipulates:—"9. The gas, on being burnt, must not yield any obnoxious products; in fact, no other products than those usually formed by the combustion of hydrocarbons."

Among about 400 towns in Germany and Austria, the gas-works of which are in the hands of private parties, or of public companies, there are, as far as I know, only *two* which, in their contracts, allude to sulphur compounds, other than sulphuretted hydrogen; these are Stuttgart and Vienna.

The Stuttgart contract says:—"10. The gas must not contain any sulphuretted hydrogen, bisulphide of carbon, carbonic acid, ammonia, or volatile ammonia compounds; and it, therefore, must not discolour acetate of lead paper, nor produce any cloudiness in lime water or acetate of lead solution."

The stipulation for bisulphide of carbon has always been ignored. The company supply gas without attempting to remove any bisulphide, and the official gas tester appointed by the town has never made any complaints.

At Vienna, the gas-works belong to the Imperial Continental Gas Association. Their agreement says:—"13. In testing the gas for sulphuretted hydrogen, moist acetate of lead paper, left in contact with a current of gas for one minute, must not assume a brownish colour; bisulphide of carbon must not be found in larger proportions than 30 grains per 100 English cubic feet."

In testing for ammonia, litmus paper, reddened with ordinary vinegar, and exposed to a current of gas for one minute, must not turn blue.

Here, again, no steps have ever been taken to remove the bisulphide of carbon. In those German towns where the gas-works are in the hands of the civic authorities, such as Berlin, Leipzic, Dresden, Cologne, &c., sulphur compounds, other than sulphuretted hydrogen, are not taken into account, and not a single German gas-works has made any purifying arrangements which aim at the removal of such sulphur compounds.

Only once, in October, 1875, the sulphur question was raised at Breslau by Dr. Meusel, who sent a report to the police authorities, in which he stated:

"Still more dangerous are the sulphocyanates discovered by me in gas, most of which form sulphocyanate of ammonium. The vapour of this compound escapes either unburnt, or it yields highly poisonous products of combustion."

This assertion was refuted by Professor Poleck, who, in his report, says, among other things:

"This amount of sulphur in the form of bisulphide of carbon and isosulphocyanates, or other sulphuretted hydrocarbons, determined in two experiments, was found to be 0·334 gramme, and 0·144 gramme per 100 litres of gas; in round figures about 15 grains and 6½ grains per 100 cubic feet. It is a fact fully ascertained by scientific investigation, that sulphocyanate of ammonium and its products of combustion are never found in gas, for the simple reason that it is not volatile without undergoing decomposition. The vapour of sulphocyanate of ammonium in gas is an illusion of Dr. Meusel, and its utilization to alarm and to disturb the inhabitants of our town must be condemned in the strongest terms. The traces of cyanogen which sometimes may be found in a strongly smoky flame, and the amount of phenyl, oil of mustard, and similar sulphur compounds, which, on being burnt, produce sulphurous acid, cannot, on account of their infinitely small proportion, be regarded as injurious to health. The public may rest perfectly assured as to the amount of poisonous constituents in the gas. All our narcotic articles of consumption contain violent poisons, but nobody would dream of condemning their normal use on that account. The progress in chemistry enables us to detect traces of poisonous substances. This forms one part of the scientific chemical expert, but another and equally important part consists in their quantitative determination, and in the demonstration of their importance in a given case."

The object in investigating sanitary questions is not only to warn and to protect the public against real dangers, but "also to avert any excitement arising from imaginary dangers."

Professor Poleck's report, published in full in the *Journal für Gasbeleuchtung*, 1876, page 6, has set at rest the sulphur question at Breslau; it also expresses the general opinion of all influential German gas chemists and engineers, and this opinion has always been expressed in the *Journal für Gasbeleuchtung*.

Up to about 1860 the opinion prevailed in Germany that the delicate tints of silk goods were injured by the products of combustion of sulphur compounds, and for this reason wood gas was introduced in several towns; for instance, in Basle in Switzerland.

This idea has been completely contradicted, chiefly at Crefeld—the German Crefeld. Here dyers, dressers, dealers, conditioners, and everybody connected with the trade, uses coal gas in the various branches of the trades. Towards the end of 1860, a monster declaration, signed by all these people, was published, in which they say, "We hereby state as our full conviction, and as the truth, that, after having for several years used coal gas in all localities of our silk, velvet, and velvet ribbon factories, we have not observed the least injurious effect upon our goods or their colours. On the contrary, we hereby express, with great regret, our inability to introduce gas lighting into the workmen's houses, many of whom, especially the weavers, work at home, and with light delicate colours on the looms." The use of gas would avert the evil effects of lampblack upon the freshness of the woven materials. Since that time the objections to gas in the silk trade have disappeared, and Basle has without hesitation discontinued wood, and adopted coal, gas.

Mr. E. Grahn, gas and water engineer at Mr. Krupp's Steel-Works, at Essen, another known authority, writes under date of April 24 last; he refers to the great weight of Dr. Schilling's opinion, which he fully endorses in every particular. He says, "We Germans shall be very glad if we are able, in however small a degree, to assist our English professional brethren in getting rid of this sulphur plague or vexation."

Parliamentary Intelligence.

HOUSE OF LORDS.

MONDAY, JULY 2, 1877.

Petitions in favour of the Bishop Auckland District Gas Bill were presented from Inhabitants, &c., in Heighington, Evenwood, &c., Eldon Lane, &c., Escomb, &c., and South Church.

THURSDAY, JULY 5.

The House went into committee on the Reservoirs Bill, and amendments were made.

HOUSE OF COMMONS.

TUESDAY, JULY 3.

The Lords amendments to the Bristol United Gas and the Newcastle and Gateshead Water Bills were agreed to.

THURSDAY, JULY 5.

The Gas and Water Orders Confirmation (Abingdon, &c.) Bill (Lords) was read the first time, and referred to the Examiners.

FRIDAY, JULY 6.

The East Worcestershire Water Bill (Lords), as amended, was considered.

The Examiners reported that the Standing Order applicable thereto has been complied with in the case of the Gas and Water Orders Confirmation (Abingdon, &c.) Bill (Lords).

Miscellaneous News.

BRITISH ASSOCIATION OF GAS MANAGERS.

(*Continued from page* 21.)

TUESDAY, JUNE 12.

At the Evening Sitting, the following Lecture was delivered on

THE STRAINS UPON GIRDERS, TRUSSES, AND BRACED STRUCTURES, AND THE MODE OF ASCERTAINING AND CALCULATING THEM.

By Mr. THOMAS CARGILL, C.E., B.A., T.C.D., A.I.C.E.,
President of the Society of Engineers.

Mr. President and Gentlemen,—It is not necessary for me to advert to the importance of the subject which I have the honour of bringing before you this evening, or to impress upon you the serious consideration and attention it claims from every engineer engaged in the designing and execution of works of a constructive character.

It is but recently, comparatively speaking, that iron trusses and framed structures have received that recognition of their theoretical and practical merits which they unquestionably deserve. For many years after the introduction into this country of tubular and plate girders, and other varieties of the solid-sided form, the lattice and similar open-sided descriptions of girders remained not only unnoticed, but were even condemned by many engineers of eminence. If we investigate the causes which led, for a considerable time, to the exclusion of these light and elegant structures in favour of their heavier and clumsy-looking rivals, we shall discover the reason why the former were kept so long in the background, and why the Commissioners appointed nearly 30 years ago to inquire into the "application of cast and wrought iron to railway structures," came to the conclusion that "lattice girders were of doubtful merit."

One of the causes to which I have alluded was a prejudice in favour of the solid-sided, girder, which, under the circumstances, was but natural. This prejudice was no doubt created, and subsequently fostered, by the exceptional manner in which the tubular, the box, and the plate girder became, for a time, the universally adopted types of construction. A particular form of bridge which successfully carried a double line of railway over a span, which at the present day has never been surpassed, under similar conditions, must necessarily at that time have appeared to engineers to comprise the *ne plus ultra* of bridge-building. The solid-sided form of girder sprang at once into general favour and use, and there is no question but that many engineers never thought for a moment of looking for any other kind. They were content to make the usual and somewhat slavish concession to precedent, and to imitate to the best of their ability the examples before them. Unfortunately for the progress of the trussed girders, it is much easier for an incompetent person to make a good shot, to use a common expression, at designing a solid than an open-sided girder.

The second cause, which very materially contributed to retarding the adoption of the open-web system, was that little or nothing was known respecting the manner in which the various strains were propagated throughout the different members of braced structures. Their theory was not understood. A mere glance at some of the earlier examples of trellis and lattice girders is quite sufficient to demonstrate how very crude and imperfect must have been the ideas of the designers, with regard to the nature and direction of the strains acting upon them, and the duty demanded of the separate parts. This is especially to be noticed in the designing of the web, in the proper arrangement of which consists the real economy of the open-sided form. This is only what might be expected, since the strains in the flanges of both solid and open web girders are similar in character and equal in amount under the same conditions. So also are the shearing strains, or the vertical components of the flange strains, but the resultants of these are peculiar to the open web girder, and require an especial mode of treatment. The cause, however, of all others, which retarded the more general adoption of braced structures, was the selection of very defective and badly-designed examples for the purposes of experiment. I shall call your attention to this point a little more particularly, for several reasons. In the first place, that you may perceive wherein the defects of the examples consisted; secondly, because this style of girder, making due allowance for some slight improvements, owing to more knowledge and information on the subject being available than formerly, is still very much used; and thirdly, because the erroneous and unjust general conclusions formed by eminent authorities, and based upon particular premisses, should be a warning to us not to place a blind belief in the inviolability of precedent, nor to accept, without some inquiry, the truth of the motto, "*Ab uno disce omnes.*"

VALUE OF CONSTANTS.

The object of all the various experiments upon the strength of materials and girders, simple and compound, which were carried out about the time of the proposed erection of the Britannia and Conway Bridges, was to determine the value of certain constants, by the aid of which a general formula could be devised for calculating the breaking strain of any particular example of construction. It is not my intention, gentlemen, on the present occasion, to enter into the mathematical details of complicated formulæ or equations, because I am well aware that no audience, even when conversant with the subject, as in the present instance, can follow, with satisfaction to themselves, oral statements of difficult and abstruse mathematical investigations. I shall, therefore, confine myself to bringing before you the results of such investigations and experiments, together with such other information as may serve to institute a comparison between the different forms of braced structures, and also to ascertain, as far as practicable, their relative suitability for various purposes. The general formula for the breaking weight of flanged girders is

$$W = \frac{A \times D}{L} \times C \qquad (1)$$

in which W represents the breaking weight in tons at the centre of the girder, A the net area in inches of one flange, D the depth, L the clear span, and C a constant, which has a different value for each particular description of girder. This formula consists of two distinct parts—the theoretical and the empirical. The former may be represented by the portion $\frac{A \times D}{L}$, and the latter by the remaining factor, C.

As there is no difficulty in accurately ascertaining the value of the first part of the formula, which is common to all flanged girders, it is obvious that the strength of any particular class of girder will depend upon the value of the constant, C. This value must be determined by direct experiment, and it is manifestly, therefore, of the greatest importance that the example selected for the experiment should be in every way as perfect as theory and practice can make it. That this was the case in determining the constant for tubular and solid-sided girders, there is no doubt. That it was not the case with respect to the open-sided class, I shall proceed to point out.

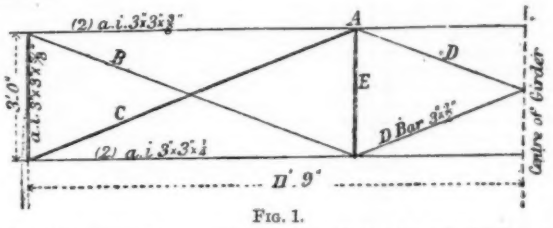


FIG. 1.

One of the open web or braced girders selected for experiment, from which to determine the value of the constant, C, is shown in fig. 1. This class of girder is very much used at the present day, although it is both theoretically and practically an unscientific and wasteful form of construction. When employed, as it generally is, to support a permanent fixed load, as was the case in the experiment, one set of the diagonal bars, B or C, is entirely superfluous, and the same remark holds good for the central bars, D. If subjected to a rolling load, the double diagonal bars, D, will be required at the centre, but not at the ends, unless the rolling load be exceedingly disproportionate to the fixed or permanent. It may be laid down as a rule that, where three sets of bars, one vertical and two diagonal, are shown in the web, one set may be dispensed with. Three are redundant. The example in fig. 1, which represents a girder 23 feet 6 inches long, and 3 feet deep, was tested with a weight at the centre, and with only 1½ ton at the apex, A, the diagonal, C, commenced to buckle, and when the weight was increased to 4 tons, the deflection reached nearly 3 inches. This apparent anomaly is readily accounted for when we consider the strains produced upon the bar, and how ill adapted it was to resist them. Theoretically, the angle which the bar, C, makes with the horizontal, which is 23°, is so flat as to cause the weights of 1½ ton and 4 tons to induce strains upon it to the amount of 4 and 10½ tons respectively. Had the bar, C, been inclined at the economical angle for that description of bracing, which is 36° or 37°, the corresponding strains would have been 2¾ and 6¾ tons. With the bar, C, inclined at the most economical angle, or 45°, the resulting strains would have been reduced to a minimum of 2 and 5½ tons. The importance of using the economical angle for bracing is thus apparent. Practically the bar, C, which was a flat bar 3 inches by ⅜ inch, was not of the proper form to resist any strain of compression whatever. To obtain the value of the constant, when the other quantities are known, by transposing equation (1) we have

$$C = \frac{W \times L}{A \times D} \qquad (2)$$

In the present instance, this equation gave for the constant for open web girders

$$C = 44 \qquad (3)$$

or about half the value of the constant for tubular and box girders, which is equal to 80. If we investigate the unit strains which the different parts of this girder were undergoing at the time of its failure, we shall perceive how very weak they were. With a breaking weight of 16 tons at the centre of the girder, the ultimate strain per square inch upon the top and bottom flange was only 11·4 tons, and upon the diagonal bars only 9 tons. In the experiments made upon the large model of the Britannia Tube, the mean ultimate strains of tension and compression were 18·6 and 14·8 tons per square inch. This example, and the manner in which it failed, is very useful in pointing out how the ultimate strength of a trussed girder is affected by an unscientific arrangement, and consequent inherent weakness of its various members, and proves most conclusively that no structure, simple or compound, is stronger than its weakest part.

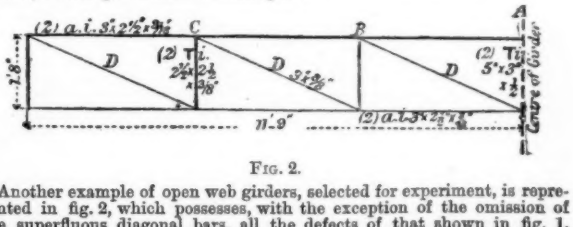


FIG. 2.

Another example of open web girders, selected for experiment, is represented in fig. 2, which possesses, with the exception of the omission of the superfluous diagonal bars, all the defects of that shown in fig. 1, together with some others of its own. The span of this girder is the same as that of the other, whereas its depth is reduced to 1 foot 8 inches, or about 1-13th of the span, which is not by any means an economical proportion for open web girders. The manner in which the different parts of this girder are proportioned, or rather disproportioned, is exceedingly bad. Each of the struts, B, C, is composed of double T-irons having a gross sectional area of 3·75 inches, whereas the dimensions of the diagonal bars, D, are 3 inches by three-eighths of an inch, equivalent to exactly a third of the sectional area of each strut. The proper proportions are actually reversed. The strains upon the bars, D, are two and a half times those upon the vertical struts, so that we have the following astounding result:—If the vertical struts, A, B, C, in fig. 2, were correctly proportioned, then

the diagonal bars, D, are seven and a half times weaker than they ought to be. If, on the other hand, the diagonal bars are of the proper scantling, then the vertical struts are seven and a half times too strong. Add to these facts that but one rivet was used to connect the bars and struts at their junction with the flanges, and it is not a matter of any surprise that this girder should break with so insignificant a central weight as six and three-quarter tons. I have drawn particular attention to the disproportion existing in this instance between the areas of the struts and the diagonal bars, because it is a very common error in the designs of incompetent persons, and one which I have had frequently to condemn in practice. From the very small breaking weight of this girder, the corresponding ultimate unit strains on the different parts will be proportionally low. Those upon the flanges were between four and five tons per square inch. Those upon the vertical struts were 0·85 tons upon the central strut, and one ton upon each of the two struts, B and C. The strain upon the diagonal bars was 7·5 tons per square inch. The value of the constant deduced from this girder was very low, and gave C = 17·8.

A more crude, inefficient, and defective piece of construction than this girder it would be difficult to imagine, and to have chosen it as an example for experiment, upon which to establish a rule for future calculation, constitutes one of the fittest illustrations of the Latin maxim, "*Fiat experimentum in corpore vili.*"

Unsatisfactory and inconclusive as the experiments which I have alluded to may seem, yet it was upon them that no less an authority than the late Sir William Fairbairn founded his opinion of all the open web class of girders, which he expressed as follows:—"All this class of open girders are, however, weak, uncertain as regards workmanship, and not to be compared with those which have a solid web connecting the top and bottom flanges. It is inferior in strength, and power of resisting the violent vibratory action of a passing train, to the more solid structures of the plate and tubular girders. In the course of my experience I have seen no reason to change the opinions I had previously expressed on the uncertain character of trussed girders, and I still advise the exercise of great caution in their employment, from the conviction that they are equally unsound in principle and dangerous in practice." Let us now look at the relative position of these two great types of construction. The tubular girder, with its complicated and unnecessary arrangement of rectangular cells is obsolete, a thing of the past, never to be employed again. The box girder is very nearly in the same category, thus leaving the plate girder as the sole representative of the solid-sided principle. The increasing use of lattice and trussed girders, and their almost general application to large railway bridges, is the best refutation of the observations I have quoted, and proves that the opinion of the great engineer was, at the least, somewhat premature.

This portion of my subject would not be complete unless I deduced a value for the constant, C, applicable to open web girders. The mean of the two values already found is C = 30·9, which is much too low. From two other experiments, with the details of which I need not trouble you, the mean value of C was 59·9. Taking the mean of this, and the previous value, 30·9, we obtain a value C = 45·4, which is also too low. If we reject the constant 17·8, which was obtained from the breaking of the very defective girder represented in fig. 2, and take the mean of the others, the value of C will equal 54·6, which is much nearer the mark, and not far from the constant for a plate girder. The actual value of the constant will, in some measure, depend upon the character and position of the girder. In the case of a pair of large lattice girders, erected for the purpose of railway traffic, braced together at the bottom by the cross girders and roadway, and also by over-head bracing at top, properly designed and proportioned, I should not hesitate to take the maximum value of C, which is 75. Where the girders are not braced together at top, the value may be put at 70. These constants are to be employed only for girders which have double webs. For a single-web girder, the value of the constant should not exceed 60, unless the span is small, when it may be put at 65. In the application of these different constants, an engineer must, as in most other instances, use, to some extent, his own judgment and discretion.

Open Web Girders.

In instituting a comparison between various forms of girders and trusses, and the resulting strains upon them, it will be impossible to bring before your notice all the manifold combinations of parts which are classed under those heads. I have, therefore, selected those examples which are the most strongly characteristic of the particular class to which they each belong, and in which the greatest points of contrast are to be found.

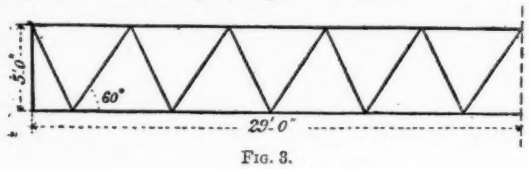


Fig. 3.

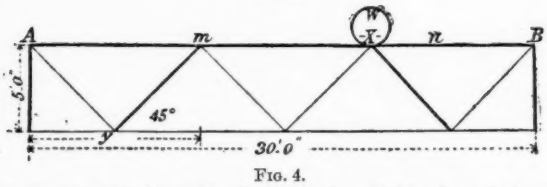


Fig. 4.

Commencing with the girders, I will take the primitive form of the open web class with parallel flanges, which is commonly known as the Warren girder, and is represented in fig. 3. Although originally made of cast iron, the name is applied indiscriminately to a girder of any material, provided it retain its distinctive features. These are, that there is only one system of triangulation in the web, and that the triangles are equilateral. This latter feature is not always adhered to in the more modern examples, of which one is shown in fig. 4, in which the triangles are isosceles. In the former the angle between the diagonals and the flanges is 60°, in the latter 45°. Let us compare these two. The number of diagonal bars in the equilateral system in fig. 3 is obviously more, and their aggregate length and weight greater than in the isosceles example in fig. 4. But, on the other hand, the strains upon the diagonal bars in the former are less than those upon the latter. The strains are in the ratio of the cosecants of the angles of inclination, and those on the bars in fig. 4 exceed those in fig. 3 by about 20 per cent. This trifling advantage for the equilateral system is more than counterbalanced by the additional quantity of material, owing to the greater number of bars required in the web in fig. 3, which amounts to as much as 35 per cent. Comparing the angles of inclination of the diagonal bracing in figs. 4, 3, 2, 1, if we represent the quantity of material required in fig. 4 by 10, then, in round numbers, that in fig. 3 will be represented by 12, and in figs. 2 and 1 by 15.

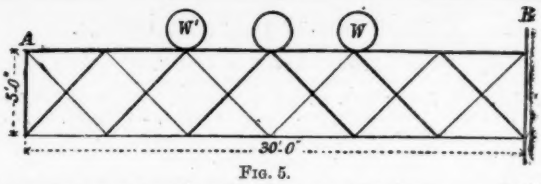


Fig. 5.

Let us now consider the question of the single *versus* the multiple system of triangulation, and we may assume that both are inclined at the same angle. The former is shown in fig. 4, and the latter in fig. 5, which represents the simplest form of a lattice girder, or that in which there is but one intersection of the bars in the web. It will be seen, on referring to fig. 4, that the bars divide the flanges into fewer parts than in fig. 5, and that when the girder becomes of a moderately large span, those parts of the flanges between the apices of the triangles become small beams or girders themselves, and undergo a very appreciable transverse strain, resulting from their own weight and the load on them. This is a direct violation of the law which ought to govern all braced structures, the fundamental principle of which is, that the various members should be subjected to strains only in the direction of their length, the object of all bracing being to convert transverse strains into longitudinal strains of tension and compression. If they are once permitted to be affected by a transverse or cross strain, they are liable to distortion, and the value of the particular form of construction is lost. It is, therefore, obvious that in large girders, the flanges, when the single system of triangles is employed, would require an extra amount of material in them beyond what the actual strains upon them demand, in order to stiffen them against the transverse strain, and so prevent deflection. Besides, as this extra material would be needed quite as much at the ends as at the centre, the gradual and economical diminution of sectional area in the flanges, from the centre towards the ends, cannot be effected. It follows from this that in large girders with parallel horizontal flanges, in which the single system of triangulation is used, theory cannot be reduced to practice. Theory prescribes a gradually decreasing strain upon the flanges from the centre to the ends, which calls for a commensurate decrease in the sectional area or in the depth of the girder. The latter dimension is fixed, and the cause to which I have drawn attention prevents the former being reduced in the proper ratio. A very great disadvantage of the single system of bracing is that it localizes the strains upon the flanges, to a very serious degree, at the intersections of the flanges and diagonals. Any one who has seen large girders of this class, such as those very frequently sent out to India, must have been struck at the large amount of additional material and workmanship, in the shape of gusset-pieces, plates, and rivetting required at those points.

The duty of a web of a girder, whether it be of the solid or open form, is threefold. It has to transmit the strains reciprocally from one flange to the other, to maintain the flanges at a constant distance apart, or, in other words, to preserve the depth of the girder constant at any given point, and to support the flanges at such intervals that they may be free from any transverse strain or tendency to deflect. The single system of bracing (see fig. 4) performs only the first part of its duty. It does not subdivide the flanges at intervals sufficiently short to ensure either of the other two requirements. If we refer to fig. 5 we shall find that the multiple system of bracing thoroughly fulfils these necessary conditions, and, in addition, possesses several other advantages which qualify it for employment in girders of the largest span. Independently of the reasons already given, which practically put a speedy limit to the single system of web bracing, it is obvious that the increase of depth alone which would occur in girders of large span, would cause the diagonal bars to become so long that those in compression could not be secured from deflection without an enormous sacrifice of material. The multiple system of triangulation not only supports the flanges at more frequent intervals, thus causing the strains to be brought upon them in a more gradual manner, instead of *per saltum*, but performs the very important work of subdividing the diagonal bars at their intersections, and thus preventing the struts from being deflected in the plane of the girder. An increase of depth in the lattice girder is attended with no disadvantage with regard to the use of long compression bars, since it is only necessary to increase the number of points of intersection on the diagonals, by introducing additional systems of triangulation.

Calculation of Strains.

There are several methods of calculating the strains upon open web girders and trusses, some of which are more convenient than others, according to the particular form of the example to which they are to be applied. Those examples which we have just considered, present greater facilities than any others, and admit of a ready computation of the strains upon them, by a few simple formulæ and equations. The various modes of calculation may all be reduced to two—viz., the analytical, and the geometrical or graphic method; and they again depend upon three fundamental principles. These are the law of the lever, the resolution of forces, and action and reaction, or the equality of moments. Let us take the case of a weight, W, upon one of the apices of the girder in fig. 4, and calculate the strains induced by it upon the flanges, and bars in the web. We must premise the following conditions:—Let the weight divide the girder, whose span is L, into two segments, m and n, and let the reaction or vertical resistance of the supports, A and B, be R and R_1, respectively. By the laws of the lever

$$R = \frac{W \times n}{L} \text{ and } R_1 = \frac{W \times m}{L}$$

The leverage with which the reactions take effect at any point, y, is the distance of y from the support A, so that putting M for the moment of strain, we have $M = \frac{W \times m \times y}{L}$

When $y = m$, the moment of strain becomes $M = \frac{W \times m \times n}{L}$. In this case y has its maximum value, and it follows, therefore, that the moment of strain upon the flanges of a girder from any weight upon it, is greatest at the point of application of that weight. The actual strains upon the flanges may be obtained from the moments by dividing by the depth of the girder, or by multiplying them by the cotangent of the angle of inclination of the diagonals with the flanges. The strains upon the diagonal bars lying between the weight and either of the abutments, are uniform, and equal to the product of the reactions of the respective supports, and the cosecant of the angle of inclination. If the weight, W (fig. 4), be moved to the centre of the girder, then m will be equal to n, and the product of the segments will be a maximum, and equal to the square of half the span, from which is deduced the well-known formula—

$$S = \frac{W L}{4 \times D} \qquad (3)$$

which represents the strain upon the flanges at the centre of a girder from a weight placed at that point. The strains may also be obtained by the principle of the resolution of forces, of which I shall presently speak more fully. If the reaction at A of the weight, W, be resolved at the point of its application, in the directions of the horizontal flange and the diagonal bar, the strains upon each are thus obtained. Resolving the strain upon the diagonal bar in the directions of the lower flange and the next bar, the strains upon them are obtained, and so on in succession until the support is reached. It must be kept in view that the strains upon the flanges are cumulative, and must be added together in order to give the total strain upon any one particular bay lying between the weight and the support. A check upon the accuracy of the operation is afforded at the support. When the strain upon the last diagonal is resolved in the direction of the upper flange and the end pillar, the strain upon the latter must equal the vertical reaction of the support, or that portion of the weight, W, which the laws of the lever cause to be transmitted to the support. The strains upon those parts of the girder situated between the weight and the support, B, are obtained in a similar manner. Whatever may be the number of weights upon a girder, a repetition of the calculations or resolutions I have mentioned would give the several strains due to each, or their sum would represent the total upon the different parts of the truss. When the number of weights becomes very great, and close together, the girder is said to be uniformly loaded. The same methods of calculation can be employed, but the results present several important differences from the case of a single weight. The formula for the strain at the centre of the flanges becomes

$$S = \frac{W \times L}{8 \times D} \qquad (4)$$

or half that when the total weight is at the centre. The strains on the flanges obey the same law as in the former case, but those upon the bars vary, being very small, and in some instances equal to zero upon those bars at the centre, and a maximum upon those at the support. The action of a moving load tends to complicate the strains upon the diagonals in the web, and causes the somewhat paradoxical circumstance of the strains upon the bars being greater with a partial than with the total rolling load. A reference to fig. 5 will render this plain. Let the rolling load be supposed to extend on each side of the centre from W to W_1, which are two apices belonging to the same system of triangulation. The portion of the load resting upon the intermediate apex will affect the bars of its own system, but not those of another. Since the weights, W and W_1, are equal, and situated at equal distances from the centre of the girder, the reaction of W at the support A, is equal to the reaction of W_1 at the support B.

This reaction of W causes a compressive strain upon the diagonal immediately under it, while, at the same time, the diagonal undergoes a tensile strain of equal amount from the reaction of W_1 at B. Since it is an axiom that a bar cannot undergo strains of compression and tension at the same time, the algebraical sum of these strains is zero. Exactly the same effect takes place with the diagonal immediately under W, and therefore these bars are absolutely free from strain under the conditions that the whole moving load is upon the girder. If we now imagine the rolling load to have advanced only as far as W, and that that weight represents its amount and position, we remove the weight W_1. The compressive strain upon the diagonal under W, due to the reaction of that weight at the support A, still remains; but as the weight W_1 is removed, there is no counterbalancing tensile strain upon the bar. Instead, therefore, of the two diagonals being free from strain, they are now subjected to a compressive and tensile strain equal to the product of the reaction of W, multiplied by the cosecant of the angle of inclination of the bars and flanges. A comparison of figs. 4 and 5, combined with the fcat that the weights upon one system of triangulation do not affect the others, will point out that for some purposes, with moderate spans, the single system is superior to the multiple system of triangulation. If a girder is loaded with weights at regular intervals, so as to suit the apices shown, for example, in fig. 4, the introduction of an intermediate system would be a mere waste of material, and in such a case the Warren girder is the most economical form to adopt. A familiar instance is that of a girder carrying the rafters of a roof on the ridge and furrow principle. I have frequently seen very wasteful forms of girders used for this purpose. When we have heavy rolling loads to deal with, the advantage of the multiple system is too evident to require any further comment.

Before leaving the subject of girders with parallel flanges, I must draw your your attention to the two formulæ representing the strains upon the centre of the flanges of a girder, first, when the weight is situated at the centre; and, secondly, when it is uniformly distributed. The one formula is double the other, from which has been deduced the following well-known rule:—"A girder will support twice the weight, uniformly distributed over it, which it will at the centre." With respect to braced girders, this assumption is not true, as may be inferred from what has been already stated with regard to the strains upon the web under different conditions of loading. Let a weight, W, be supposed to rest upon the centre of a girder as in fig. 5. The strain upon all the diagonals is uniform, and is equal to $\left(\frac{W \times \text{cosecant } \theta}{2}\right)$ = half W multiplied by the cosecant of the angle between the diagonals and flanges. As the latter factor is a constant in the same girder, the shearing strain, or vertical component of the diagonal strain, may be taken as the basis of comparison. With a central weight, W, this is equal to half W throughout the whole web. With an equivalent uniform load of 2 W, the strain upon the central diagonals is equal to zero, while that upon the end diagonals will be equal to W, or twice the amount due to a load at the centre, which is assumed to produce only equal strains upon the girder.

The Bowstring Girder.

While the lattice girder is no doubt susceptible of a much greater extension than it has hitherto received, there is another form of construction which possesses some especial advantages, when large spans and heavy rolling loads have to be provided for. This girder is the Bowstring, the most economical form of which is represented in fig. 6.

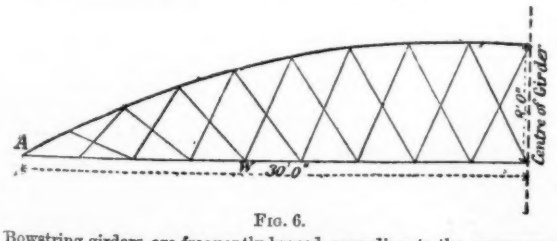


Fig. 6.

Bowstring girders are frequently braced, according to the arrangement shown in the previous figures for girders with parallel flanges; but the remarks I have made regarding the economy of bracing apply to this form of girder as well. When the load is uniformly distributed over a bowstring girder, the strains on the flanges—that is, in the bow and string respectively—are nearly uniform throughout each of them. There is, therefore, but very little waste of material in the flanges of this girder. With the load distributed as stated, the strains upon the diagonals increase from the ends towards the centre. This is exactly the reverse of what occurs in girders with parallel flanges. The strains upon the flanges may be calculated by the formulæ Nos. 3 and 4, and, if the curve of the upper flange were a true parabola, they would be perfectly uniform throughout both the bow and string; but as, in practice, the arc of a circle is always employed, the strains increase slightly in the bow towards the ends, in proportion to the secant of the angle formed by a tangent to the curve at any point. In ordinary examples, the total increase does not exceed above 8 per cent.

The principal theoretical difference to be noticed between girders with parallel flanges and those which have the upper flange curved, as in fig. 6, is that, in the former, the whole of the shearing strain passes along the diagonal bars. In the latter, a large portion of it is taken by the bow, which thus very much relieves the diagonals of strain. The diagonals in a bowstring girder are, comparatively, very lightly strained. The readiest method of calculating the strains upon a bowstring girder is to take the action of each weight separately, and then tabulate the results. Let us consider the weight, W, in fig. 6. The laws of the lever will give the vertical pressure upon the support, A, which, by a diagram of strains, can be resolved in the directions of the bow and string respectively. The strain upon the last bay of the bow can then be resolved in the directions of the next bay and the first diagonal, and so on throughout the entire girder. The bowstring girder is not an economical form for small spans, owing to the workmanship being more expensive than in girders of uniform depth. But it is exceedingly well suited for railway bridges of very large span, in which the permanent weight of the structure itself would bear a considerable ratio to that of the moving load. Under certain relative conditions, the strain upon the diagonal bars would be always of a tensile character, and there would be no necessity for counterbracing them. The objections frequently urged against long struts would then no longer exist, since the only part of the girder liable to a compressive strain would be the bow, which, for practical reasons, would be of a sectional area and form well adapted for resisting a strain of that character. By the employment of steel, which would admit of a high unit strain, bowstring girders could be built without difficulty up to spans of 1200 feet.

An important feature in the bowstring girder is that it admits of great depth of truss, and thus reduces the strains upon the flanges, which are in the inverse ratio of that dimension.

Roof Trusses.

The examples of braced structures that I am now going to bring to your notice are generally employed in the construction of roofs. The number of the parts and the different angles at which they are inclined, both to a horizontal line and to each other, render the application of mathematical formulæ, to the calculation of the strains upon them, exceedingly laborious and complicated. The strains are obtained in a much simpler and readier manner by the geometrical or graphic method. There are several ways of applying this method, but the one which I consider to be altogether the most satisfactory is that known as "the successive resolution of forces at each joint." Another very elegant and conclusive mode is what is known as the "polygon of forces." In order that the relative merits of

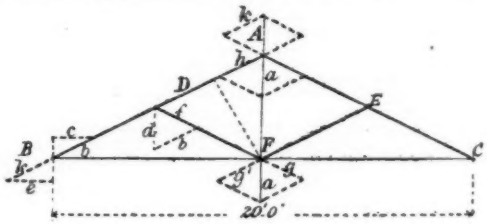


Fig. 7.

the two principles may be clearly demonstrated, I have selected a simple king-post roof, shown in fig. 7, suitable for spans of about 20 feet, and calculated the strains by separate diagrams. Assuming the total load in one principal to be two tons, we shall have one ton on each half principal, which will be distributed as follows over the rafter:—Half a ton at the points D and A, and a quarter of a ton at the point B. The weight at B is directly supported by the side wall, and does not enter into the calculation. I well first consider the principle of the successive resolution of forces at each joint. At the point D, draw a vertical line, *d*, to represent the weight at that point. This weight is evidently supported by the joint action of the lower portion of the rafter, B D, and the strut, D F. Resolving *d* in the direction of these bars, we shall have the compressive strain upon the rafter equal to *b*, and that upon the strut equal to *f*. The strain *b* will be uniform throughout the lower part of the rafter, and may be supposed to pass down it until it reaches B, where it will be resisted partly by the vertical reaction of the support, and partly by the pull of the tie-rod, D F. Resolving *b* in these directions, we obtain a tensile strain upon the tie-rod equal to *c*. The portion of the weight upon the point D passing down the rafter is now accounted for, and we have now to consider the other portion passing down the strut, D F, and represented by *f*. At the centre of the tie-rod at F this strain is met by one equal and opposite from the other strut, E F, which gives a resultant, as shown by the parallelogram of forces at that point, equal to *a*, which represents the total pull on the king-post, A F. This strain is transferred to the apex, A, where it is resisted by the two rafters, and being resolved in their respective directions will give a compressive strain upon each equal to *h*. Both portions of the rafter, A D and D B, will be affected by this strain, which at the point B may be decomposed as before, and will give another strain upon the horizontal tie-rod equal to *e*. We have only now to consider the action of the weight at A, which is directly supported by the resistance of the two rafters. Being resolved in their respective directions, it will give another strain upon the rafters equal to K. This strain will also be impressed upon A D and D B, and being decomposed at B will give a third strain upon the tie-rod, B F, which completes the process. The strains may now be summed up and tabulated, when it will be found that, confining our attention to the half principal, there will be one strain on the strut, D F, one on the king-rod, A F, two upon the upper portion of the rafter, A D, three upon D B, and three upon the tie-rod, B F. In this instance, the total strains are multiples of the single strain, but this is not always the case.

This method can be also used by commencing the resolution of forces at the support, and starting with the vertical reaction at that point. In that case some of the strains upon the rafter must be subtracted instead of added. There are also a few particular examples of braced structures in which the operation must be commenced with the vertical reaction of one or other of the supports.

Polygon of Forces.

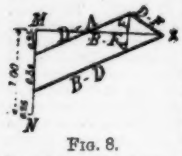


Fig. 8.

The diagram in fig. 8 represents the application of the "polygon of forces" to the strains upon the half principal shown in fig. 7. The line M N is the load line, upon which are laid off the portions of the total weight upon the rafter. The diagram is drawn to suit the directions of the members of the left half truss in fig. 7. Commencing at the point N, the portion of the weight directly supported at the point B is plotted upon any convenient scale, and a line drawn parallel to the rafter A B. The distance between this line and the other parallel to it in the diagram, fig. 8, is equal to the portion of the weight supported at D. The remaining part of the line is equal to half the weight supported at the apex, A. The total length of the line is equal to the total load upon the half principal. To determine the correct length of the lines in the diagram which are equal to the corresponding strains, we draw from the point M a line parallel to the horizontal tie, B F, in fig. 7, to cut the line already drawn parallel to the rafter. The line B D in fig. 8 represents the total strain upon the part of the rafter B D in fig. 7, and the line B F represents the corresponding strain upon the tie. From the point where the lines B D and B F intersect in fig. 8, draw D F parallel to the strut D F in fig. 7, to cut the line D A in fig. 8 drawn parallel to the rafter in fig. 7.

The line D F in fig. 8 will represent the strain upon the strut. From where D F intersects D A in fig. 8, draw A F parallel to the king-rod in fig. 7 to meet B D in fig. 8, and it will represent the total strain upon the king-rod, and complete the diagram.

Of these two methods it will be at once apparent that the latter—that is, the "polygon of forces—affords not the slightest information respecting the manner in which the strains are arrived at. It gives the total strains, similarly to a mathematical formula, but does not indicate how they are the result of several separate strains added together, each of which is due to some particular action of the weight upon the different parts of the structure. It does not trace out the effect of the separate weights throughout each individual member of the truss, as is done by the method shown in fig. 7, and although it accomplishes the same task, it leaves the person employing it completely in the dark with regard to the *modus operandi*. I strongly advise all beginners, and those studying the subject, to employ, in the first instance, the principle of the "successive resolution of forces," and then use the other as a check upon the former. A certain amount of reasoning and synthetical investigation must attend the employment of the successive method, whereas the other is, to a great extent, purely mechanical. Any one who thoroughly understands the "successive" principle, and has applied it to trusses of any particular form, will have little difficulty in applying it successfully to others; whereas a person may learn by rote, as it were, a certain number of diagrams of the "polygon of forces" applicable to a certain description of trusses, and yet be unable to draw the diagram for an example which is new to him. Some of these diagrams, under the conditions of partial loading and wind pressure, assume very extraordinary and eccentric outlines. Simple and elegant as the method of the "polygon of forces" undoubtedly is, it requires to be used with caution, or it may lead to very erroneous results.

It has been urged against the "successive" method that any errors committed in plotting off the weights and strains are cumulative, and that, therefore, there may be a large error in any total strain. This objection has no practical foundation, and may be considered merely as an excuse for bad and careless plotting. I have taken out strains by this method for trusses of very large dimensions, and have checked the total strains, either by the "polygon of forces," or, where feasible, by direct calculation, and have never found any appreciable difference. Whenever any discrepany arose, it was not due to any gradual accumulation of error, but to some palpable mistake, which was as easily corrected as it was detected. At the commencement of this lecture, I alluded to the "method of moments," as a useful means of checking the strains upon braced structures which had been determined by other processes. We may apply it to the example in fig. 7 to check the strain in the upper part of the rafter, D A. Calling S the strain upon D A, and measuring by scale the perpendicular distance of it from F, we find it equals 4·5 feet, and we have then S × 4·5 = the reaction of the abutment, multiplied by its leverage, *minus* the moments of the weights at B and D.

Thus $S \times 4{\cdot}5 = 1 \times 10 - (0{\cdot}25 \times 10 + 0{\cdot}5 \times 5)$ from which

$$S = \frac{10 - 5}{4{\cdot}5} = \frac{5}{4{\cdot}5} = 1{\cdot}1'$$ tons, which agrees with that in the diagram.

If we compare the diagram of strains in fig. 8 with the truss itself in fig. 7, a rather curious relationship between the parts of the truss and the lines representing their corresponding strains in the diagram will be discovered. The lines in the truss which enclose a space will be found to meet in a point in the diagram, and *vice versâ*. For instance, the lines in the truss B D, D F, and B F, enclosing the triangle B D F, meet in a point, X, in the diagram of forces in fig. 8, and the lines in the diagram D F, A F, and B F, which enclose a triangle, meet in a point at F in the truss in fig. 7. It is not necessary that this relationship should always obtain, but when it does, the truss and diagram are said to be reciprocal. It is evident that this reciprocity serves as a check upon the accuracy of the operation, and should therefore be used as often as possible.

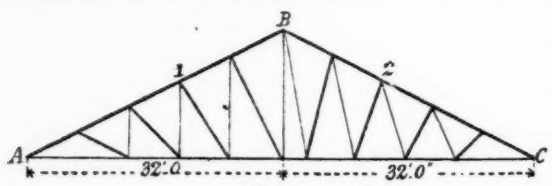


Fig. 9.

A distinct classification may be made in roof trusses between those which have the main tie horizontal, and those in which it is inclined. In fig. 9 are shown two elevations of half trusses, suitable for spans of from 50 to 70 feet, in which the only difference consists in the manner in which the bracing is arranged. So far as the resulting strains are concerned, there is no especial advantage in one arrangement more than in the other, although what little there is, which may be worth considering in a heavy roof, rests with the system 2, in which both struts and ties are inclined to the vertical. In this system the length of the struts is about one-twelfth less than in that shown in the other half of the figure.

There are two practical considerations which put a limit to the employment of trusses of this description with a horizontal tie-rod. One is the question of headway, which is frequently as important in the case of roofs as in that of bridges; and the other the difficulty of securing from flexure, with a due regard to economy of material, long unbraced struts. In both of these trusses the objections urged against the adoption of the Warren girder for large spans apply with greater force. The bracing of the Warren girder, although equally unsuitable for spans of any magnitude, is superior to that in both 1 and 2 in fig. 9, inasmuch as it is uniform in length and inclination, whilst the struts in 1, and both struts and ties in 2, are constantly altering their angle of inclination at every apex, both upper and lower, and their lengths as well. Hence, in both these trusses, one of the great principles to be observed in all constructive designs—namely, the employment of as few dissimilar parts as possible—must be necessarily almost completely ignored. Every separate bar in the bracing in 1 and 2 would require a different templet, thus causing a large amount of extra labour and workmanship.

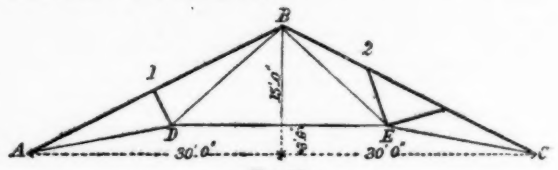


Fig. 10.

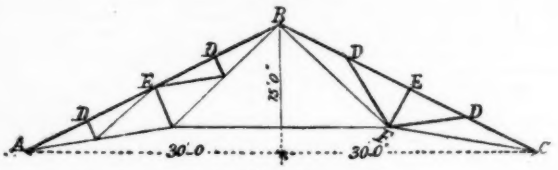


Fig. 11.

All these disadvantages may be removed, or, at least, very considerably diminished, by the employment of the trusses shown in figs. 10 and 11, concerning which I have a few remarks to make, as they exemplify in a most satisfactory manner the most important features of a good truss. In fig 10, the trusses 1 and 2 are similar, with the exception that 2 is intended for a larger span, and has two struts supporting the rafter instead of one. The points particularly worth noticing in these trusses are—first, the fewness of parts, and secondly, the radiation of the most important members of the truss from one point, as at D and E. This is a feature to which sufficient attention is not paid in the designing of braced structures. Thirdly, the shortness of the struts; fourthly, that the longest and principal parts, if we omit the rafter, are in tension. These advantages are not all gained without some accompanying sacrifice. The effective depth of the truss is diminished by the raising of the inclined tie-rod, so that the strains upon all the members are increased. In truss 2 there is less waste of material in the rafters than in 1, since the effect of the second strut is to render the strains more uniformly distributed upon the upper and lower parts of the rafter.

The strains on the various members of roofs with double trusses, similar to figs. 10 and 11, depend partly on the pitch of the roof, and partly on the angle between the rafter and inclined tie-rod. There is a certain relation between these two angles, which renders the strain on the tie, A D or E C, exactly double that upon D B and E B, thus enabling the same scantling of bar to be used in both places by simply doubling the bar. I was the first to point out this relation, some time ago, in one of our leading scientific journals. I need not enter into the investigation of the subject here, but will give the result. Calling the angle of the pitch of the roof θ, and the angle between the rafter and inclined tie-rod θ_1 the relation is expressed by the equation—

$$\tan \theta_1 = \frac{3}{5} \tan \theta$$

$$\text{or, } \tan \theta_1 = 0{\cdot}6 \tan \theta$$

This proportion can always be adhered to, so long as it does not entrench upon the proper value for the depth of the truss, which must, to some extent, regulate the value of the angle of the pitch of the roof, that is the angle θ. Theoretically these conditions between the strains on the tie-rods will hold independently of the values of the angles θ and θ_1; but, practically, the limit is reached when $\tan \theta = \tan (90 - \theta)$. When this limit is attained, the ties, D B and E B, become vertical, and the horizontal tie disappears. The limiting value of θ, in actual construction, will not, therefore, exceed 52°.

In fig. 11 two half trusses are shown in elevation, which are adapted for larger spans than the example in fig. 10. A little consideration of the half truss 2, fig. 11, will demonstrate that the remark I have previously made with regard to the feature of a number of parts of a truss meeting in the same point, does not always hold good. Apart from all other considerations, something depends upon the position of the load which will determine which members of the truss are struts, and which are ties. But for this, the truss 2 would be superior to truss 1, inasmuch as there are five bars meeting in a point in it, whereas in truss 1 there are only three. It will be readily seen, however, that the latter truss is in every way superior to the former. In truss 1 the struts, with the exception of the centre one, which is common to both, are a great deal shorter, and instead of being inclined at a bad angle to the rafter, as in 2, are perpendicular to it, thereby materially lessening the strains upon them. In fact, the practical efficiency and relative merit of these two examples depend upon the length of these struts. The inclined struts in 2 are exactly twice the length of the centre one, in both 1 and 2, and the strains from similar weights in the same proportion, so that the truss 7 is capable of being economically used for spans of nearly twice the length of truss 2. This truss errs on the score of having too small a number of separate parts, which is quite as much a mistake as to have too large a number. Truss 1 is an excellent form of construction, and well adapted for large spans; indeed, with the exception of the centre strut, which is strained twice as heavily as the shorter ones, owing to the pull of the two small ties upon it, this truss may be said to be altogether in tension, omitting, of course, the rafter. The small ties are necessary to prevent transverse strain upon the long inclined ones, owing to the weights upon the small struts. The strains upon the trusses in fig. 11 may be determined by the same process as already described for the example in fig. 7, and checked by the diagram shown in fig. 12, one-half of which gives the total strains for truss 1, and the other for truss 2. It will be interesting to briefly compare these strains in the diagram, because it will serve to indicate that the introduction of subsidiary or smaller trusses very frequently does not affect the total strains upon the parts of the principal truss. First, with regard to

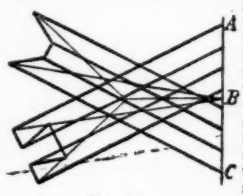


Fig. 12.

the rafters. The maximum strain upon each rafter—that is, the strain upon the lower end portion of each—is the same in both examples. In truss 2 the strain upon the middle bays of the rafter is much less than in truss 1, in which the strains are, as seen from the diagram, nearly uniform throughout the rafter. As practically the rafters of roofs of this description always have a uniform section, there is less waste of material in truss 1 than in truss 2.

Curved Roofs.

When the span of a roof exceeds 100 feet, it is more economical to abandon the straight raftered system, and employ the arched or circular form, of which an example is represented in fig. 13 in half elevation.

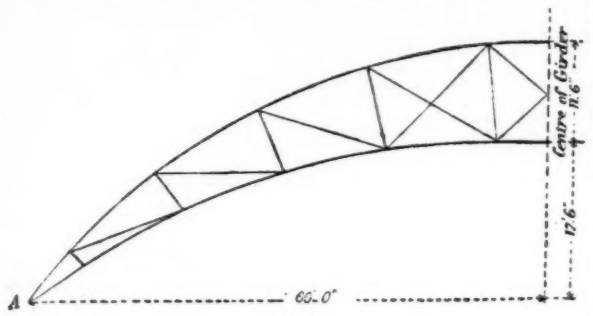


Fig. 13.

The web or bracing of these roofs may be arranged in various ways. It is very frequently designed on the panel principle—that is, with vertical struts and double diagonal ties—and then possesses the disadvantages already mentioned with respect to that method of bracing. A better plan is to brace the principal, as shown in fig. 13, in which the struts are made as nearly perpendicular as possible to the arch. Sometimes this bracing is reversed, and the long bars made struts, and the short ones ties, in which case the struts slope in the contrary direction—that is, towards, instead of from, the abutments. The bracing can be arranged as shown on the figure. The strains upon roofs of this description may be calculated by the method already described, by commencing at the end of the girder with the vertical reaction of the abutment, resolving it in the direction of the last bars of the upper and lower flanges, and thus obtaining the total strains upon them. By finding the resultant of the first-named strain, and the weight at the first joint, and resolving it in the direction of the upper flange and the first strut, the strains upon them are determined, and so on for the other parts of the truss. The strains may be checked by the "polygon of forces," and by the method of moments. The points to be noticed, with regard to the strains upon structures of this kind, are the following:—The strains upon the bracing, under a symmetrical load, are very slight, which at once indicates that most of the shearing strain is taken by the arch, as might be expected from what has been said about the bowstring girder. The strain upon the flanges is compressive in the upper and tensile in the lower, and nearly uniform, increasing slightly towards the centre, which is exactly opposite to what occurs in a bowstring girder. At the centre the horizontal strain in either flange is equal, but this equality is not continued in the other bays of the upper and lower flanges. As a rule the separate strains in the bays of the upper flange exceed those in the corresponding bays of the lower. Owing to the fact that the strains upon the bracing are slight, this form of truss is well adapted to roofs of large span, especially when the covering is of a heavy kind. The strains upon the struts and ties in the web follow no regular law or series. The constant alteration of the angles of inclination, and the curved character of both flanges, prevent any regular increment or decrement of strain upon not only the bracing but upon the flanges themselves. It should be noticed with regard to this truss, or crescent girder as it has been called, that the strains are not affected by the rise of the tie above the line of springing, but depend altogether upon the effective depth or distance between the two flanges. Occasionally these girders are constructed with a uniform depth. In that case they virtually become arched ribs similar to the design of the roof of the St. Pancras Railway Station. The tie of this gigantic roof consists of a number of continuous wrought-iron girders, and extends underneath the station from side wall to side wall. The span of this roof is 240 feet, and the reason alleged for this exceptional dimension, and for all similar designs, is the assumed necessity for a clear space below, unincumbered by columns or supports of any kind whatever. It is very questionable whether this necessity really exists. Wherever space is available for a railway station of the size of that at St. Pancras, the introduction of one or two intermediate rows of columns could not be productive of any inconvenience. As in the case of bridges, the cost of a roof increases in a far higher proportion than that of the span, and where practicable, a succession of moderate spans is a rule more economical than one gigantic roof clearing the whole area.

Conclusion.

While it cannot be denied that the want of acquaintance with the principles which govern the designing of the structures, which have formed the subject of my lecture this evening, has led to many failures, and to the erection of many defective and wasteful examples, yet, on the other hand, neither bridges nor roofs can be built from calculations and diagrams alone. Theory and practice, in order to constitute the well-qualified engineer, must go hand in hand. The days are gone by when a natural aptitude for engineering pursuits, and great practical sagacity, combined with some amount of experience, were sufficient to deal with the questions which arose.

Our constructive engineering of the present time is of far too costly a character, and upon a scale of magnitude, which does not admit of either incompetent designing or faulty execution. If a girder or truss, either for a bridge or a roof, be designed too theoretically, so to speak, it will not be an economical example. If it be designed too practically—that is, without due attention given to the amount of the strains upon it, it will also display an absence of economy, although the causes in the two instances will be widely different. In the latter design there will generally be found a waste of material. In the former the material will be properly distributed, but the waste will occur in the workmanship and connexions. I have seen bridge girders in which there was an evident straining to carry out to the fullest extent theoretical principles, to the total exclusion of other equally important practical considerations. The result was that the girders cost £40 per ton, instead of about half that sum. The waste of material is particularly noticeable in the earlier examples of open web girders and trusses, in which the designers, in order to be on the safe side, as it is termed, took care to put in plenty of material. Unfortunately, this did not always ensure the security of the structure, as the absence of material in other parts, where it was equally important, sometimes led to its downfall. The recent fall of the Ashtabrela Bridge, in America, which was attended with such lamentable results, furnishes a case in which, while the trusses were theoretically strained far below their safe working limits, yet they gave way, owing to the utterly incompetent manner in which they were designed and constructed. In that instance, both theory and practice were wholly defective, and the entire structure was a complete libel upon bridge-building. In order to design efficiently and economically engineering structures, the engineer must be well acquainted with the methods of connecting together ironwork of different sections and scantlings, as seen in the workshop, and by combining his practical knowledge and experience with the proper leaven of theory and science, he will be able to solve the great problem of all constructive designing—namely, the "putting the right quantity of material in the right place."

Wednesday, June 13.

Mr. C. Woodall (London) read a paper on

Some Experiments upon Power and Fuel Expended on Exhausting Gas.

It has happened at various times, but especially within the last few weeks, that I have had occasion and opportunity to make some careful experiments upon the power required to drive exhausters doing a certain amount of work, and upon the most economical way of obtaining that power.

In offering to the Association the results of those experiments, I am influenced by a hope that they will prove of interest and service to the members, and also by the circumstance that there is so little published data on the subject.

Beyond an interesting article in *Engineering* of May 21, 1875, founded upon some experiments made by me at the Vauxhall works, and to which I shall, with your permission, refer in the course of my remarks, I do not know of any such data. This being the case, it is hardly to be wondered at that there is apparent in different gas-works a vast difference in the plant provided for driving exhausters, and consequently in the money spent thereupon.

While my experiments have been made with three different types of engines, the exhausters have all been of the same class—viz., the ordinary rotary exhauster patented by Mr. J. Beale, and subsequently altered, and possibly improved, by several makers. I know that many engineers who have used other forms of exhausters, claim for them advantages over Beale's, but into that matter I have not had opportunity to examine. What I have attempted to determine is the power required, with a certain standard type, to do a given amount of work, and I trust we may have from members present some figures as to others.

The character of fuel used in these trials has varied—steam coal, coke, and breeze having each been tried. As, however, in each case, the result is stated in pounds of water evaporated per 1000 cubic feet of gas exhausted, there is no confusion in the tables; while we obtained some useful comparative data as to the value of these respective fuels to steam users.

I will now proceed to describe the plant used, and the method in which the experiments were conducted; and, for the purpose of comparison, I will, with your permission, briefly quote those already referred to as published two years ago.

First, then, a horizontal non-condensing engine was used, the crank-shaft of which was coupled direct to the shaft of an exhauster designed to pass 100,000 cubic feet per hour.

Secondly, a beam-engine, single-cylinder condensing, driving two exhausters, each of the same size as in the former case (100,000 feet per hour), made by Messrs. Burton, Sons, and Waller, through a system of geared wheels. The non-condensing engine had a cylinder 12 inches diameter and 24 inches stroke, the beam 20 inches diameter and 30 inches stroke.

The steam was supplied from a Cornish boiler 26 feet long by 6 feet diameter, with a flue tube 3 feet diameter, and a fire-grate 6 feet by 3 feet, or 18 superficial feet area.

The trials lasted for ten hours each day; the engines were used for exhausting only, the water being pumped into the boiler by a donkey pump worked by steam brought from elsewhere. The feed water was carefully measured, and the water in the gauge-glass brought to the same line at the end as at the commencement of the experiment. The fire was drawn at the commencement of each experiment, and again at its close, when the fuel remaining unconsumed, as also the ashes and clinkers, were duly weighed. Indicator diagrams were taken, and the pressure of steam in the boiler observed every half hour, and the observations of the speed of the engine checked by a counter kept going through the trial. The quantity of gas passing was taken hourly from the station-meter register, and all possible care was taken to avoid error in any direction.

Good Welsh steam coal (Ballfa) was used on the day the condensing engine was at work, gas coke with the non-condensing.

The results obtained were as follows:—

—	Beam Condensing with two 100,000 Exhausters and Gearing.	Horizontal Non-Condensing with one 100,000 Exhauster coupled Direct.
Duration of trial	10 hours.	10 hours.
Average pressure of steam	28½ lbs.	36 lbs.
Average speed of engine	29¼ revolutions.	80·6 revolutions.
Average indicated horse power	25·9	21·9
Gas exhausted per hour	108,800 cubic feet.	106,140 cubic feet.
Vacuum, inlet exhauster	3 inches.	3 inches.
Pressure, outlet exhauster	40½ inches.	38 inches.
Total fuel used	1556 lbs. (coal).	2238 lbs. (coke).
Fuel used per square foot of fire-grate area per hour	8·6 lbs.	12·43 lbs.
Fuel used per indicated horse power per hour	6·0 lbs.	10·22 lbs.
Per centage of dirt	7·1 per cent.	10 per cent.
Feed water—		
Temperature	60 degs.	62 degs.
Evaporated, total	14,244 lbs.	16,700 lbs.
Evaporated per hour	1,424 lbs.	1,670 lbs.
Evaporated per indicated horse power per hour	55 lbs.	76·25 lbs.
Evaporated per pound of fuel	9·2 lbs. (coal).	7·46 lbs. (coke).
Fuel used per 1000 cubic feet passed	1·43 lbs. (coal).	2·11 lbs. (coke).
Water evaporated per 1000 cubic feet	13·1 lbs.	15·75 lbs.
Indicated horse power exerted per 1000 cubic feet	0·238 lb.	0·206 lb.

The same engines were again tested last month under rather different conditions. The boiler used was again a Cornish one with single flue,

its dimensions being 24 feet by 5 feet 9 inches, flue 3 feet diameter, with six 2½ inch tubes 6 feet long within it. Fire-grate 7 feet by 3 feet, or 21 feet superficial area.

The non-condensing engine had again to drive its 100,000 feet exhauster coupled direct, while the condensing engine drove one made to pass 120,000 feet per hour by wheels and shafting, the wheels geared two to one. Both exhausters were of J. Beale's patent, and made by Messrs. B. Donkin and Co.

The results in this case were as follows:—

—	Beam Condensing Engine, and Driving one 120,000 Exhauster and Gearing.	Horizontal Non-Condensing, and Driving one 100,000 Exhauster Direct.
Duration of trial	10 hours.	10 hours.
Average pressure of steam	36·6 lbs.	34·5 lbs.
Average speed of engine	22·25 revolutions.	62·09 revolutions.
Average indicated horse power, of 40 diagrams	13·56	10·33
Gas passed per hour	78,000 cubic feet.	75,000 cubic feet.
Vacuum, inlet exhauster	1·6 inches.	1·5 inches.
Pressure, outlet exhauster	27·7 inches.	27·3 inches.
Total resistance	29·3 inches.	28·8 inches.
Coke used, less cinders, per hour	1047 lbs.	1288 lbs.
Coke used per square foot of fire-grate area per hour	5 lbs.	6 lbs.
Coke used per indicated horse power per hour	7·7 lbs.	12·5 lbs.
Per centage of dirt	13½ per cent.	12¾ per cent.
Feed water—		
Temperature	75 degs.	73·3 degs.
Evaporated, total	7592 lbs.	10,497 lbs.
Evaporated per hour	759 lbs.	1,049 lbs.
Evaporated per indicated horse power per hour	56 lbs.	101½ lbs.
Evaporated per pound of coke	7¼ lbs.	8·100 lbs.
Coke used per 1000 cubic feet	1·340 lbs.	1·750 lbs.
Water evaporated per 1000 cubic feet	9·700 lbs.	14·000 lbs.
Indicated horse power exerted per 1000 cubic feet	0·174 lb.	0·137 lb.
Power required to drive engine alone at speed given	1¾ indicated horse power.	2½ indicated horse power.

The largely increased weight of steam, per indicated horse power, required by the non-condensing engine in the second trial over the first, is, I think, explained by the fact that the cut-off was the same in both cases, though the work was so materially varied.

A comparison of the ultimate results of the two trials shows (as would naturally have been expected) that the power required, per 1000 cubic feet, is, within ordinary limits, directly proportioned to the pressure on the outlet of the exhauster.

Needing to extend the exhausting plant at the station where these trials had been made, I determined to put down a much more economical engine than those we had been using. I, therefore, advised the purchase of a compound condensing engine, and one of that class, of 30-horse nominal power, was accordingly procured from Messrs. B. Donkin and Co. The makers gave a guarantee that the consumption of steam, per indicated horse power, should not exceed 22½ lbs. when the engine was putting out about 30-horse power, and the steam in the boiler was at 50 lbs. pressure. To ascertain how nearly this efficiency had been attained, and also with the object of obtaining a few more facts to lay before you, I had a very careful trial of this engine made last week, the details of which I will now describe:—

Experiments on 30-Horse Power Steam-Engine at Phœnix Gas-Works, Vauxhall, June 5, 1877, made by Messrs. Woodall and Donkin.

Class of Engine.—Horizontal, compound condensing; low-pressure cylinder, steam jacketed. Diameter of cylinders, 12 inches less 1-64th, and 20 inches less 1-64th from gauges; length of stroke, 2 feet 3 inches and 2 feet 3 inches.

Boiler (new), Lancashire.—Two flues, draught dividing down sides, and returning under bottom. Dimensions, 22 feet long, 6 feet 2 inches diameter; flues 2 feet 4 inches diameter; grate surface 21 square feet (each grate was reduced from 6 feet to 4 feet 6½ inches in length, and ash-pit partially closed with loose bricks to contract air space).

Pressure of Steam taken every half hour by tested Bourdon gauges:—

Mean of 21 readings	35½ lbs.
Duration of trial from 9.20 a.m. to 7.20 p.m.	10 hrs.
Vacuum in condenser, taken half-hourly	28¾ ins.
Revolutions per minute, taken by counter	46·8
Indicated horse power developed in high-pressure cylinder (average of 42 diagrams)	10·37
Ditto low pressure 42 „	11·52
84 „	21·89

Indicator Diagrams taken from top and bottom of each cylinder every half hour by four Richards's indicators:—

Water from Condenser.

Initial temperature of injection water (average of 28 readings)	67·79°
Ditto water discharged from air-pump (average of 60 observations)	92·17°
Rise of temperature in condenser	24·38°
Height of water over tumbling bay, 3 inches wide (average of 60 observations)	2¾ less 1-32nd
Mean discharge per minute	334 lbs.
Pounds per indicated horse power per minute	372

Water from Steam Jacket.

Quantity discharged per hour	66 lbs.
Ditto do. per indicated h. p. per hour	3 „

Feed Water.

Quantity evaporated during ten hours	5666 lbs.
Ditto do. per hour	566 „
Ditto do. per indicated h. p. per hour	25·8 lbs.
Ditto do. per lb. coke consumed	9·46 „

No water was pumped into boiler. Experiment commenced with water in gauge-glass as high as possible, and finished near the bottom, using in all 9¾ inches in the ten hours. Feed-valve shut off. The contents were calculated from very minutely-taken dimensions of inside of boiler, and checked by feeding in next day at the same pressure.

Coke.

Fair quality and size, weight per chaldron		12¾ cwt.
Quantity used in ten hours	672 lbs.	
Less cinders drawn from fires	73 „	
		599 lbs.
Ditto per square foot fire-grate per hour		2·85 lbs.
Ditto per indicated horse power per hour		2·75 „
Weight of dirt and refuse not burnt—		
Clinkers	20 lbs.	
Ashes	46 „	
		66 lbs.

or 11 per cent. of fuel used.

Remarks.—Fires drawn at beginning and end of experiment. Steam used for no other purpose. All valves tight.

Work.—Driving one 150,000 feet per hour J. Beale's patent exhauster, with outside bearings, made by Messrs. B. Donkin and Co., by straps through a short piece of shaft. Gas passed per hour (average) 73,300 cubic feet. To absorb as much power as possible, the outlet valve was closed down partially.

Pressure on exhauster (average of 20 readings)	48½ ins.
Vacuum „ „ „	2½ „
Total resistance to exhauster	51 ins.
Coke used per 1000 cubic feet passed	0·82 lbs.
Water evaporated per 1000 cubic feet passed	7·72 „
Indicated horse power exerted „	0·298 „
Indicated horse power to drive engine alone	3½

It is necessary to remember, when noticing the result of this trial, that the engine was working at a disadvantage, because of the light work upon it in proportion to its power. As it was, the result was very satisfactory.

Permit me now to call attention briefly to the points I consider worthy of observation arising out of these experiments.

First, as to the power required for exhausting. Taking out from the results the item of indicated horse power per 1000 cubic feet of gas exhausted, it is as follows:—

Non-Condensing Engine coupled direct to Exhauster.

Indicated horse power per 1000 cubic feet at 29 ins. pressure		= 0·137
Ditto do. 1000 „ 38 „		= 0·206

Beam Condensing Engine driving Exhauster through Gearing.

Indicated horse power per 1000 cubic feet at 29 ins. pressure		= 0·174
Ditto do. 1000 „ 40 „		= 0·238

Compound Condensing Engine driving Exhauster by Straps.

Indicated horse power per 1000 cubic feet passed at 51 ins.	= 0·268
The same engine tested at 26 inches	= 0·181
Ditto do. 24 „	= 0·162
Average of the five experiments at 34 inches	= 0·199

And from that average I conclude that, allowing for the constant of the engine, which would become a larger per centage of the whole as the pressure was reduced, the power required to exhaust 1000 cubic feet of gas against a pressure of 15 inches under average conditions is equal to from 0·095 to 0·1 of an indicated horse. Of course, if the arrangements for driving are complicated the power will be greater, and where the exhausters are driven direct, without the interposition of gearing or straps, it will be less. I would again remark that I am here treating of rotary exhausters of the Beale pattern only; no doubt some of the other forms in use require less power, while again others may take more. On this subject we may hear something from members present.

I turn now to the question of the most economical way of obtaining the power. Taking out the item of water evaporated per 1000 cubic feet of gas exhausted, the figures stand thus:—

Non-condensing, against 41 inches pressure	15·73 lbs.
Beam „ „ 43 „ „	13·09 „
Compound „ „ 51 „ „	7·72 „

I prefer, however, to take as the item for comparison the water evaporated per indicated horse power. Questions of gearing or straps or direct action would, of course, affect every engine alike, and the experiments I have detailed show, so far as they go, to what extent. These are expressed, however, in the power exerted, and the steam used to obtain the power is the measure of the efficiency of the engine. This comparison stands as follows:—

Water Evaporated per Indicated Horse Power.

Non-condensing engine	76·25 lbs.
Beam „ „	56·00 „
Compound „ „	25·00 „

I leave out the second trial of the non-condensing engine, which gave 101 lbs. per indicated horse power for the reason already given.

Now I have already shown that the average power put forth in these experiments amounted to 0·199 indicated horse power per 1000 cubic feet of gas exhausted, and that a correction for pressure from 34 inches, the average of my trials down to 15 inches, which is more nearly the average met with on gas-works, would give 0·1 as the power requisite per 1000 cubic feet. From this I deduce the following figures, taking for illustration a gas-work making 50,000 cubic feet per hour, and assuming that make maintained through the year.

Water to be Evaporated per Hour.

Non-condensing engine	76·25 × 0·1 × 50 = 381·25 lbs.
Simple „ „	56·00 × 0·1 × 50 = 280·00 „
Compound „ „	25·80 × 0·1 × 50 = 129·00 „

Taking coke as the fuel to be used, and putting its evaporative power per lb. at 7·5 lbs. water, the consumption comes out.

No. 1	381·25 × 24 × 365 = 3,339,750 ÷ 7·5 ÷ 2240 = 198·8 tons.
No. 2	280·00 × 24 × 365 = 2,452,800 ÷ 7·5 ÷ 2240 = 146·0 „
No. 3	129·00 × 24 × 365 = 1,130,000 ÷ 7·5 ÷ 2240 = 67¼ „

For the works where the trials were made, and at the average pressures there, the consumption of coke amounts to 728, 533, and 285 tons respectively.

Assuming the coke to be worth 12s. per ton, the comparative cost would be—No. 1, £121 8s.; No. 2, £87 12s.; No. 3, £40 7s.

I need hardly point out that the saving effected by the use of an economical engine is by no means confined to the diminished cost of fuel. The saving in boilers and water evaporated may fairly be set against the increased cost of the engine, but the saving in labour is a clear gain. In my own case that amounted to one-half, for we found, so soon as our new engine was started, that one man could do comfortably the work which had fully occupied two before.

On the question of fuel it is often urged that saving in that direction is of small moment on a gas-works; that the disposal of coke and breeze is frequently so difficult, that the better price obtained for a smaller sale covers a wasteful expenditure. With this view I cannot coincide; the quantity of fuel saved will be sold at the market price, and that should

content us. For my own part, I cannot see why we should not be as pleased to produce cheap coke as cheap gas, and I am often surprised to see how earnestly companies strive to maintain a high price for their coke in order that they may slightly reduce the price of their gas. The former is purchased by as large a number of consumers probably as the latter, and those of a class to whom a low price is of even greater moment. So long, therefore, as the price of gas is within the parliamentary standard, I see no reason for studying one class of consumers more than another.

I have to apologize to the Association for the bare way in which my figures have been presented, and to express a hope that they may possess sufficient interest to excuse their dryness.

Mr. R. O. PATERSON (Cheltenham) was pleased to see that Mr. Woodall had incorporated in his paper the experiments recorded in *Engineering* in May, and had compared them with those more satisfactory trials which he had subsequently made. He was pleased, moreover, that Mr. Woodall had not only given the meeting the results of his trials, but had worked them out in such a way that they would be of great service to the members of the Association in making their own comparisons. When he (Mr. Paterson) was working up the paper he had the honour to lay before the meeting on the previous day, he made some experiments with his boiler, comparing results with those recorded in *Engineering*. It would, perhaps, be wearisome to read the figures, but he should be pleased to have them inserted in the report, and taken as part of his remarks. [The following paper was handed in]:—

—	Phœnix Gas Company. From *Engineering*, May 21, 1875.	Cheltenham Gas Company, April, 1877.		
Boiler	26 feet long × 6 feet diameter.	Galloway, 16 feet long × 5 feet diameter. One flue.		
Fire-grate	6 feet × 3 feet.	6 feet 2 inches × 2 feet 6 inches.		
Gross flue heating surface	594 feet superficial.	270 feet superficial.		
Ratio of gross heating surface to fire-grate area	32·44 : 1	17·42 : 1		
		No. 1.	No. 2.	No. 3.
Coke burnt	2,238 lbs.	8,064 lbs.	5,012 lbs.	3,052 lbs.
Water evaporated	16,709 lbs.	41,016 lbs.	22,946 lbs.	18,218 lbs.
Water evaporated per pound of coke	7·46 lbs.	5·08 lbs.	4·57 lbs.	5·97 lbs.
Mean temperature of feed	62 degs. Fahr.	49° Fahr.	42° Fahr.	46° Fahr.
Mean pressre. of steam	36½ lbs.	52·6 lbs.	52·2 lbs.	52·6 lbs.
Ashes at end of trial	119 lbs.	504 lbs.	342 lbs.	224 lbs.
Clinkers at end of trial	166½ lbs.	196 lbs.	146 lbs.	98 lbs.
Ashes and clinkers in per centage of fuel used	10 per cent.	8·67 per cent.	9·73 per cent.	10·55 per cent.
Water evaporated per square foot of gross heating surface per hour	2·86 lbs.	1·27 lbs.	1·18 lbs.	1·41 lbs.
Coke burnt per square foot of grate per hour	12·43 lbs.	4·33 lbs.	4·49 lbs.	4·10 lbs.
Mean speed of engines in revolutions per minute	80·61	—	—	—
Mean indicated horse power	21·90	—	—	—
Consumption of water per indicated horse power per hour	76·25 lbs.	—	—	—
Gas passed per hour	106,140 cubic feet.	17,983 cubic feet.	18,847 cubic feet.	15,229 cubic feet.
Vacuum on suction of exhauster	3 inches.	0·85 in.	0·93 in.	0·62 in.
Pressure on delivery side of exhauster	38 inches.	11·50 ins.	10·80 ins.	17·00 ins.
Total resistance to exhauster	41 inches.	12·35 ins.	11·73 ins.	17·62 ins.
Horse power required to exhaust 1000 cubic feet of gas	$\frac{21·90}{106·14}$ = ·2065 HP.	—	—	—
Consumptn. of steam required to exhaust 1000 cubic feet of gas	$\frac{21·9 \times 76·25}{106·14}$ = 15·73 lbs.	19·18 lbs.	16·83 lbs.	24·92 lbs.

The water evaporated per foot of grate surface, he found, in the experiment to which Mr. Woodall referred as having been recorded in *Engineering*, was 2·86 lbs. in the arrangement when coke was used for fuel, and in the experiment he (Mr. Paterson) made himself, he found the consumption of fuel was 1·27 lbs. of coke. He was not quite sure what gave rise to such a great difference. It would, however, be open to investigation and question. The consumption of water per 1000 feet of gas exhausted was, he thought, given in *Engineering* as 15·75 lbs., in the worst type of engine Mr. Woodall referred to; and in the case of the steam-jet which he (Mr. Paterson) had recorded, the consumption was 19·18 lbs. in the one case, and 24·92 lbs. in the other. He thought, therefore, the results of Mr. Woodall's experiments went to prove most conclusively that some steam-engines were more economical than others, and than the steam-jets in use at the present time.

Mr. MORTON (London) remarked that Mr. Woodall mentioned how his exhausters were driven in the first two cases—one was direct-acting from the crank-shaft to the shaft of the exhauster, the other by the intervention of an intermediate shaft and gearing. But he did not mention how the third was driven, and it would be interesting to know what was done in that case.

Mr. WOODALL said he did not expect a discussion upon his paper, and, in fact, had intended to offer it for the use of the Association in the way that Mr. Paterson had offered his tables. But he thought, upon reflection, that it was a matter which might very fairly be brought before the meeting, in the hope that some manufacturers, amongst the extra-ordinary members, might favour them with some particulars of machinery produced by themselves. As to Mr. Morton's query, he might remark that he did state in his paper that in the third case he was driving from the engine by straps from a short piece of shafting. The reason why he did that was that he preferred to have one good engine, as being more economical than a number, requiring both less attention and less fuel.

The PRESIDENT said the importance of Mr. Woodall's paper must not be estimated by the short discussion that had taken place upon it. In truth, its value was very considerable; it furnished a kind of information, the importance of which could not really be over-estimated. It was a paper consisting of practical statistics, and would enable the members to study and compare notes, and see whether they could come at all up to the standard of the writer, who, it was well known, was a very exact experimenter whose results might be accepted without any question whatever. But beyond all that, it opened up a wide field—the question of fuel for driving exhausters. It was not to be considered as a question by itself. There were correlative advantages and disadvantages, and the additional expenditure of fuel in some instances might be possibly compensated for in other ways. He was sure he expressed the feeling of the meeting when he said the Association were much indebted to Mr. Woodall for his paper.

(To be continued.)

TRANSFER OF THE CLITHEROE GAS-WORKS TO THE CORPORATION.

The gas-works of Clitheroe were purchased from the company by the corporation of that town in February last, it being arranged that the company should work the concern to the end of the financial year—viz., the 30th of June, immediately after which date the plant and all the property of the company should be formally transferred to the corporation. A meeting for this purpose was accordingly held in the board-room of the works on Monday, the 2nd inst., which was presided over by the MAYOR (Mr. J. Mitchell), and attended by the chairman of the company (Mr. W. B. Dewhurst), several of the directors, and some of the members of the town council.

The CHAIRMAN of the company, in handing over the keys of the safe and the works, said he was very happy to have the pleasing duty of handing over such valuable works as the Clitheroe Gas-Works had hitherto proved to be. He had been connected with the company a great number of years; he had known the concern when it did not pay any dividend at all, but through the very excellent management which had been exercised of late, the company had been able to pay full maximum dividends, with a very nice balance tied to the stock. He hoped that the works would prove as prosperous in the future as they had done in the past. He thought the Mayor would have no cause for regret at having made such an excellent purchase as the Clitheroe Gas-Works, and if the council would only manage the undertaking with the same economy that had hitherto been exercised by the board of directors, he could not see why it should not be as fruitful.

The MAYOR said it was a great gratification to him to take part in these proceedings, particularly as it was the second time in his life of having been the purchaser of gas-works. He thought there were not many mayors who, during the time of their mayoralty, in the short space of nine months, would be able to say that they had purchased two such valuable concerns as the gas-works and water-works of Clitheroe. He was very much pleased with the way in which the negotiations had been conducted. The directors had been willing to approach the matter in a fair and reasonable spirit, and he was bound to say that there had not been a single word of discord during the whole of the negotiations. He congratulated the directors upon having successfully worked the undertaking and brought it to so prosperous an issue, and he hoped the council would never have reason to regret the bargain they had made. The mayor then handed over the keys to the manager (Mr. W. Miles), hoping that he would do as well for the corporation as he had done for the shareholders of the company.

An adjournment then took place to the Swan Royal Hotel, where dinner was provided jointly by the mayor and the chairman of the company. After the usual loyal toasts,

Mr. MILES, the manager of the gas-works, addressed the meeting. He said he had been the manager for the last eleven years, during which period the consumption of gas and the income of the company had doubled. He hoped that matters would go on as well in the future as in the past, and, as far as he was concerned, he would endeavour to do his duty. There had been various attempts to supersede the use of gas, but without success. Water gas had been introduced, air gas had been introduced, magnesium light had been introduced, the electric light had been brought forward, and the latest novelty, about which great expectations were entertained, was the electric candle. The exhibitions of this new light in this country had hitherto not been very encouraging, and for himself he held the opinion that the time was very far distant when gas would be superseded.

THE THEORY OF THE BUNSEN LAMP.

By T. E. THORPE, Ph.D., F.R.S., Professor of Chemistry in the Yorkshire College of Science, Leeds.

[A Lecture delivered before the Chemical Society, March 1, 1877.*]

It is hardly necessary, in an assembly of chemists, to extol the merits or the services of the Bunsen lamp; it may be safely asserted that no single piece of our apparatus has done more to facilitate our labour or to increase our productiveness. We can only realize how intimately associated it is with our comfort as workers, when we endeavour to imagine to what we should be driven if we were deprived of it.

And it is not only to the scientific man that this instrument is of service; there are many trades to which it has become as indispensable as it is to us. But in spite of this very general application, it is only quite recently that we have obtained clear notions of its action. To this end the labours of Bunsen himself have contributed, directly and indirectly, in the greatest degree; for his studies in connexion with the general properties of gases not only led him, in the first place, to the recognition of the principles upon which the lamp is constructed, but they have served, in the second, owing to the precision which he gave to gasometric analysis, to clear up much of what has hitherto been obscure in its theory.

During the past four or five years a number of investigators have studied the phenomena presented by the Bunsen flame, more particularly in relation to the general question of the theory of luminous flames, and thanks to the observations of Blochmann, Heumann, Knapp, and others, it is now possible to offer a tolerably complete account of the theory of its action. I have thought, therefore, that a brief statement of what appears to be the present state of knowledge upon a subject of no little concern to us all as chemists, might not be without interest to the Fellows of this Society.

The story of the origin of the lamp may be told in a very few words. Bunsen, when planning the fittings of his present laboratory, had arranged for the introduction into it of coal gas as a fuel. An eminent Fellow of this Society, Professor Roscoe, had brought under his notice some of the contrivances which were then in use in this country for burning coal gas with a smokeless flame. There are doubtless many here who can well remember these pieces of apparatus; possibly to some they are associated with the memories of disasters ending in the loss of much glass and precious material, and still more precious time; these at least will not be surprised to learn that our distinguished foreign member pronounced them as unworthy of the fuel they had to burn. Bunsen's inventive power was in immediate exercise, and no very long time elapsed before Universitäts-Mechanikus Desaga was able to put his ideas into brass and iron.

Of course, it is hardly to be supposed that the lamp at once took the form and proportions of the instrument with which we are all familiar, but, as you will see from this drawing which Mr. Desaga has been so good as to prepare for me, the first lamp differed but slightly from those now used, the main alteration being in the height and width of the tube.

It is unnecessary for me to trouble you with any details of the con-

* From the *Journal of the Chemical Society*.

struction of the present form of lamp. You know that essentially it consists of a brass tube, at the bottom of which is a small opening for the entrance of coal gas; in the tube and close to the jet are holes through which air passes and mixes with the up-streaming gas, in such proportions that the mixture burns at the mouth with a non-luminous flame. That the air is actually concerned in the destruction of the luminosity of the flame is evident from the circumstance that by closing the holes in the tube, either with the fingers or with the moveable regulator, which is now commonly attached to the lamp, the flame again becomes luminous. You are also doubtless aware that, in order that the flame may not retreat down the tube, it is necessary that a certain relation shall exist between the height and width of the tube, the area of the air-holes, and the amount and velocity of the issuing gas. There are other conditions which determine the proper behaviour of the burning lamp, which we shall have the opportunity of discussing hereafter.

And first, then (to begin at the beginning), let us consider the mode by which the air is caused to mix with the inflammable gas. How is it that by piercing the tube, close to the burner, with holes sufficiently wide, air flows in and mixes with the gas in such proportions as to give a non-luminous flame? There is a well-known experiment, first made by Clement and Desormes, and mentioned in most text-books of physics, which serves to illustrate the cause. These physicists found that when a small opening was made in a box, containing compressed air, and a disc of wood or metal was held against the stream of issuing gas, the disc was forcibly driven towards the hole in the reservoir—that is, against the outrushing air—the disc oscillated backwards and forwards in the air-stream within a short distance from the orifice, and required considerable force to drag it away. Faraday was accustomed to show this remarkable and somewhat paradoxical phenomenon in a characteristically simple manner. Placing the fingers of his outstretched hand together, and holding it horizontally, he blew with some force through the interspace below the knuckles of the first two fingers upon a light card of two or three inches square placed immediately beneath; the card was lifted up and remained suspended, apparently against the action of gravity and the issuing air, so long as the blast continued. These effects are due to the existence of what the meteorologists call an area of low pressure in the neighbourhood of the orifice through which the gas rushes; the issuing stream carries with it more or less of the circumjacent air, partly as the result of its expansion, and partly as the result of its viscosity, exactly as the falling water in the trompe of the Catalan forge carries down the air. The simple arrangement which you see on the table (fig. 1), which is constructed on the principle of the multiplying manometer of Dr. List, which some of you may have seen exhibited in the Loan Collection of Scientific Apparatus, may serve to demonstrate the existence of this area of low pressure in the neighbourhood of a jet through which air rushes. It consists of a small but wide vessel (*a*) connected with a long narrow horizontal tube (*c*) partially filled with coloured spirit; as you

Fig. 1.

perceive, a very slight increase in the height of the level of the liquid in the wide vessel causes a very considerable column of the coloured liquid to flow out of the horizontal tube. If the diameter of the wide vessel at the surface of the coloured liquid be ten times that of the horizontal tube, a diminution of pressure in the wide vessel capable of raising the spirit 1 cm. high, will cause a displacement of 100 cm. in the column in the horizontal tube. You see that, when I blow into the wide vessel through the narrow glass tube (*b*) ending above the surface of the liquid, there is an immediate flow of the coloured spirit out of the horizontal tube into the large bulb.

By means of a smaller apparatus constructed on the same principle, I think I shall be able to show you the existence of this rarefaction in the

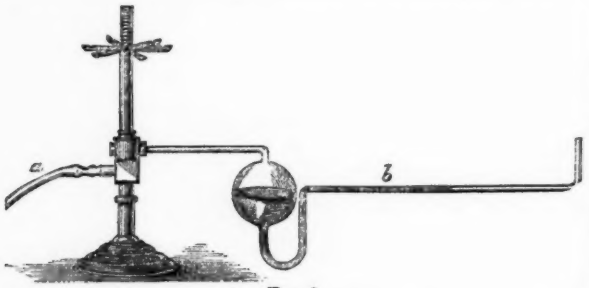


Fig. 2.

neighbourhood of the burner of the Bunsen lamp as the gas issues through it, despite the low pressure with which it is driven into the air. One of the air-holes of this lamp (fig. 2) is closed with a cork, the other is connected with a little manometer (*b*); you see, as I turn on the gas, the liquid in the narrow horizontal tube immediately flows into the wide bulb.

The intermixture of the gas and the air thus driven in is greatly facilitated by the rapid spreading out of the gas stream after leaving the burner. If you substitute a glass tube for the ordinary brass tube of the lamp, and cause the gas to burn at the bottom, you will notice from the shape which the flame assumes in the first few moments, that the gas at a height of a very few millimètres above the burner flows out in a curve towards the walls of the tube as its velocity of efflux diminishes. The flame strikes against the sides of the tube, which rapidly becomes hot, as some of us possibly know to our cost. The amount of air which thus mixes with a given volume of gas varies with the diameter and height of the tube and the area of the air-holes. In the lamp ordinarily used in laboratories, the gas becomes mixed with from half the amount required for complete combustion. Such a lamp giving a flame of about the average size—that is about 120 mm. in height, burns about 80 litres of gas under half an inch pressure in an hour. Hence you see that as much as 250 litres of mixed gases are driven up the tube of each small lamp in a laboratory in the course of an hour.

In certain modifications of the Bunsen lamp, as in the burner of Mr. Wallace, the proportion of air to gas is greatly increased. In one of the forms devised by him the gas is mixed with as much as four and a half times its volume of air. Such a mixture is within the limits of inflammability; for ordinary gas will not burn when mixed with more than eight or eight and a half times its volume of air, or with less than three volumes, at least at ordinary temperatures. Hence it is only by the special contrivance of a perforated cap that the flame is prevented from retreating down the wide tube.

This leads us to the consideration of another point connected with the theory of the lamp, which may become of paramount importance under certain conditions. You know that it is possible to burn a mixture of one volume of oxygen and two volumes of hydrogen, at the end of a narrow tube without exploding the mixture in the reservoir, provided that the explosive mixture is driven with sufficient rapidity through the tube. If the velocity of efflux of the mixed gases is greater than the rate of propagation of inflammation from particle to particle, there is no risk of exploding the detonating mixture in the reservoir; if, however, the pressure on the mixed gases is diminished, so that the rapidity of inflammation becomes greater than that of the efflux of the gases, the flame passes along the tube into the reservoir, and an explosion results. The rapidity of inflammation of a gaseous mixture depends mainly upon two factors—(1) the temperature of inflammation, that is, the temperature required to initiate the chemical union; and (2) the temperature of combustion, that is, the temperature produced by the chemical union. The rapidity of inflammation of a mixture of detonating gas, and of carbon monoxide and oxygen, has been determined by Bunsen, by observing the velocity with which the mixed gases must travel through a small aperture in order that the position of the flame may be maintained constant. He thus found that the rate of propagation of combustion in the mixture of oxygen and hydrogen was 34 mètres in a second of time, whereas in that of the carbon monoxide and oxygen it was less than 1 mètre per second. He also found, as indeed we should expect from the conditions which determine the rapidity of inflammation, that an excess of one or other constituent, or an admixture of an indifferent gas, rapidly diminished the rate. Bunsen also observed that a mixture which was inexplosive in the open air could be fired in a closed vessel, as in this case no heat is absorbed by the free expansion of the gas.

We have to thank Professor Mallard, of the French School of Mines, for a series of observations made by Bunsen's method, on the rate of propagation of combustion in mixtures of coal gas and air, and of marsh gas and air, undertaken in view of the relation of the question to the theory of safety lamps (Mallard, *Annales des Mines*, vol. viii., 1875, p. 355). Although we are more immediately concerned with the matter as affecting the special case of coal gas, it may not be uninteresting to state that, in mixtures of fire-damp and air, the maximum rapidity of inflammation was found to be about 0·56 m., or rather more than half a yard per second; this corresponded to a mixture of one volume of marsh gas and 8½ volumes of air. When the proportion of air was increased to 12 volumes or diminished to 5·9 volumes, the mixture was neither explosive nor inflammable. It is worthy of note that the proportion of air corresponding to the maximum rate of inflammation is less than that which contains the oxygen necessary for the complete combustion of the marsh gas.

The maximum rapidity of the propagation of combustion in mixtures of coal gas and air is much greater than in the case of fire-damp and air, as indeed we should be led to anticipate from the large quantity of free hydrogen which coal gas invariably contains. The maximum rapidity of the particular sample of coal gas examined by M. Mallard was 1·02 m., or rather more than one yard per second; this occurred in a mixture of 5 volumes of air and one volume of gas. As in the case of other gases, the rate is very rapidly diminished by an excess of either constituent; a mixture containing more than 8 volumes and less than 3½ volumes of air to one of coal gas was found to be uninflammable.

The results of M. Mallard's observations are contained in Table I.:—

Table I.

Vols. of Air Mixed with One Vol. of Coal Gas.	Rapidity of Inflammation in Mètres per Second.
6½	0·285
6	0·617
5½	0·820
5¼	0·985
5	1·010
4⅞	0·935
4½	0·740
3½	0·097

The bearing of these observations on the theory of the Bunsen lamp will be at once evident to you. We notice that we could burn even the most inflammable of the mixtures at the top of the tube, provided that we could maintain the ascending column at a greater velocity than 1·02 mètres per second. As we have said, the gas passing up the tube of the ordinary lamp in the case of a flame about 120 mm. high is mixed with from 2 to 2½ times its volume of air; if the proportion of air rises to 3½ volumes, the mixture would have to arrive at the opening of the tube with a velocity greater than 0·097 mètre per second, otherwise the flame would retreat. Of course, in practice, a greater initial movement than this would be required in order to provide against loss of motion due to friction against the sides of the tube, in consequence of which the centre of the gas stream always moves faster than the outlying portions. This retardation, which may be considerable in dirty or corroded tubes, frequently induces the flame to retreat; the main body of the inflammable stream may be moving with the velocity necessary to prevent retardation, whilst the sluggish outer layers are powerless to oppose it. Any arrangement which ensures that the minimum velocity of efflux of the mixture is greater than the rate of propagation of combustion, will prevent the retreat of the flame, but the most obvious course, that of increasing the gas pressure, is not always possible. In cases where the gas pressure is invariably low, perhaps the simplest method is to turn in the upper end of the tube, as proposed by Professor Morton, or what comes to the same thing, to lay a small perforated disc on the top of the tube. The rate of movement of the various portions of the gas-stream is thus equalized. The rose which is commonly attached to the lamp, the perforated cap of Mr. Wallace's burner, or the little bit of wire-gauze which we place on the top of the tube when we desire a very small flame, owe their efficacy partly to the same action, and partly to their cooling effect on the flame.

Having thus traced the progress of the mixture of air and gas up the tube, let us now turn our attention to the flame itself. In the first place, we notice that it is hollow; that is, it contains a large internal area consisting of the uninflamed mixture. The issuing stream in which the gas is mixed with only about twice its volume of air, is, as we have seen, uninflammable; it is only, therefore, at the margin, where the requisite additional amount of oxygen is met with, that combustion occurs. The existence of this internal area of unburnt and comparatively cool gas may

be demonstrated by the simple experiment of supporting a lucifer match down the tube by means of a pin pushed transversely through the splint, so that the head of the match appears a few millimètres above the mouth of the tube. On lighting the lamp, the flame appears to envelop the match, which, however, is not ignited. A piece of gun cotton placed in the same position is not inflamed. It must not be supposed, however, that the composition of the mixture is the same in all parts of the internal area, for the products of the combustion of the marginal portions find their way into the stream of unignited gas.

We are indebted to Dr. Blochmann for a series of observations on this and many other points connected with the Bunsen lamp. (Blochmann, *Ann. der Chem. u. Pharm*, 168, 295.) By methods similar to those already adopted by Landolt and Hilgard in the case of luminous flames, he has traced the gradual alteration in the composition of the mixture at different points in the internal area—viz., at 25 mm. and 50 mm. above the opening of the tube, and he has also determined the nature of the gases in the flame itself at a distance of 75 mm. from the tube. The flame studied by him was 120 mm. high, and the point of the inner zone varied from 55 to 60 mm. from the end the tube. The coal gas, which varied but slightly in composition in the course of the observations, issued under a pressure of 12 mm., and was mixed with air in the tube in the proportion of 28·26 volumes of gas to 71·74 volumes of air, or slightly more than 2½ volumes of air to 1 of gas. The per centage composition of the gases drawn from the various points is given in Table II.:—

TABLE II.

—	Mixture in the Tube 10 mm. below the Opening.	25 mm.	50 mm.	75 mm.
H	13·74	9·68	4·84	2·80
CH_4	11·02	10·78	7·64	0·99
CO	0·80	0·58	2·99	2·21
C_2H_4	1·13	0·90	0·60	—
C_4H_8	0·85	0·66	0·44	—
O	14·88	13·85	5·92	—
N	56·47	59·58	61·66	66·65
CO_2	0·21	0·93	3·55	7·25
H_2O	0·90	3·14	13·66	20·20

On comparing the composition of the gases in the tube with that of the mixture in the middle of the internal area, we see that the only important difference is that a certain amount of the free hydrogen, of which the ignition point is comparatively low and the rapidity of inflammation very high, has been consumed; the effect of this we see in the increased proportion of water vapour. We also notice, from the increased amount of nitrogen, and from the fact that the quantity of oxygen is sensibly the same as in the mixture in the tube, that an additional amount of air has been mixed with the gas. At a height of 50 mm., the effect of this admixture of combustion products with unburnt gas is more marked, and we see that the proportions of water vapour and oxides of carbon are greatly augmented.

Table III. represents the proportion of air which has mixed with 100 volumes of the coal gas at the different points, and shows, even more clearly, the nature of the changes in the composition of the mixture at the various stages of its flow and combustion.

TABLE III.

Amount of Air Mixed with 100 Vols. of Gas.	In the Tube.	25 mm.	50 mm.	75 mm.	Complete Combustion.
H	48·6	36·4	17·7	16·1	—
CH_4	39·0	40·1	28·0	5·7	—
CO	2·9	2·2	19·9	12·7	—
C_2H_4	4·0	3·4	2·2	—	—
C_4H_8	3·0	2·5	1·6	—	—
O	52·7	52·0	21·7	—	—
N	199·8	223·8	225·9	382·4	482·3
CO_2	0·8	3·5	13·0	41·7	62·4
H_2O	3·1	11·8	45·8	116·1	141·2
	353·9	375·7	369·8	574·7	685·9
Contraction	—	9·0	14·7	10·1	22·9

This table also shows us that of the two combustible gases of which coal gas is chiefly composed—namely, marsh gas and hydrogen—the hydrogen is the first to burn; we see the effect of this in its diminished proportion in the gases at 25 mm. and 50 mm. above the tube. The cause of this rapid diminution in the proportion of the hydrogen is to be ascribed mainly to the greater diffusive power of that gas, to its lower ignition-point, and to its greater rapidity of inflammation as compared with marsh gas. It is known that a red-hot wire causes the combustion of a mixture of oxygen and hydrogen, whereas it has no effect on a mixture of marsh gas and oxygen. That this rate of diminution, in the proportion of the hydrogen, can be maintained is hardly to be expected; for in the partition of the oxygen between the two combustible gases, we soon arrive at a condition of things analogous to that observed by Bunsen in the case of the combination of a mixture of carbon monoxide and hydrogen with oxygen gas. The rate of the combustion of the hydrogen very rapidly diminishes as its proportion decreases, and that of the marsh gas increases. At a height of 75 mm.—that is, at about one-third of the distance between the top of the inner zone and the visible limit of the flame, the amount of the marsh gas is only about one-third of that of the hydrogen. The increased ratio of the hydrogen is probably due to the high temperature of this part of the flame; the temperature of combustion of the marsh gas in air is high enough to prevent the complete combustion of the hydrogen, or, what comes to the same thing, is sufficiently high to dissociate vapour of water already formed. The large proportion of carbon monoxide present in the neighbourhood of the summit of the inner cone accords with our every-day experience of the reducing action of this portion of the flame.

We see from Table III. that in the combustion of coal gas a considerable contraction of volume occurs; 708·8 volumes of air and gas give only 685·9 volumes of combustion products. On the whole, the rate of the contraction goes on increasing with the height of the flame, but you notice that at 75 mm. a sudden break in the continuity of the rate is manifest. This is owing to an increase in the volume of the still unburnt gas due to the decomposition and partial oxidation of the hydrocarbons—*e.g.*, 1 volume of ethene with 1 volume of O, gives 2 volumes of carbon monoxide and 2 volumes of free hydrogen.

Blochmann has also analyzed the gases present in the extreme outer edge of the flame; these, of course, consist of water vapour and carbonic acid mixed with oxygen and nitrogen.

The results are contained in the following table:—

TABLE IV.

Height from Burner. mm.	CO_2.	H_2O.	O.	N.	$\frac{H_2O}{CO_2}$
10	3·30	14·36	8·29	74·05	4·35
20	3·49	14·95	7·95	73·61	4·29
30	4·07	14·68	8·31	72·94	3·63
40	3·95	12·90	8·94	74·21	3·27
50	3·64	11·22	10·03	75·11	3·08
60	3·92	11·02	9·72	75·34	2·81
70	4·35	10·82	9·20	75·63	2·49
80	4·91	10·73	8·92	75·44	2·18
90	5·38	10·72	8·60	75·30	1·99
100	5·73	10·81	7·76	75·70	1·89
110	6·58	10·97	6·61	75·84	1·67
120	7·18	11·14	6·17	75·51	1·55

These numbers also serve to indicate what we have before noticed—viz., that the greater portion of the hydrogen present in the coal gas is consumed in the lower parts of the flame. We observe that the greatest proportion of the water vapour is formed in the lowest quarter of the flame; it then gradually decreases up to a height of about 90 mm., after which it slowly increases. This corresponds exactly with what we noticed in connexion with the composition of the gases in the interior of the flame. On the other hand, the proportion of carbon dioxide suffers a pretty steady increase with the height of the flame, as we should expect. It should be noted, however, that the whole of the water and carbon dioxide drawn through the tube at the particular heights above given, cannot be considered as having been actually formed at those points, since there is no doubt that a certain amount of these gases must have diffused into those spaces from other regions of the flame.

Blochmann, lastly, has determined the amount of the products of combustion in the atmosphere immediately surrounding the flame, drawn at a distance of 10 mm. from the edge. His results, which are contained in Table V., show that, below a distance of 20 or 25 mm. from the opening of the tube, not a trace of the products can be found; it is only at a height of about 30 mm. that these become perceptible. The ratios in the fourth column afford additional proof of what we have before noticed—viz., that the free hydrogen burns proportionately faster than the hydrocarbons; at a height of 60 mm., and upwards, we find that the ratio of water vapour and carbon dioxide becomes constant, and almost identical with that given by the complete combustion of the gas, showing, therefore, that the marginal portions of the coal gas are completely consumed.

TABLE V.

Vertical Height from Opening of Tube. mm.	H_2O Vapour.	CO_2.	$\frac{H_2O}{CO_2}$
20	0·06	0·00	—
30	0·77	0·16	4·8
40	1·14	0·40	2·8
50	1·73	0·63	2·7
60	1·90	0·75	2·5
70	2·42	1·05	2·3
80	3·71	1·37	2·7
90	2·40	0·91	2·6
100	2·70	1·10	2·4
110	2·90	1·13	2·6
120	2·74	1·30	2·1
100 vols. of gas give	137·79 vols.	62·62 vols.	2·3

We all know that if we cover the air-holes of the Bunsen lamp with our fingers, or with the moveable cap on the tube, the flame at once becomes luminous; on uncovering the holes, we observe that it immediately resumes its ordinary appearence. What is the cause of this? The usual opinion seems to be that the coal gas has become mixed with an amount of oxygen, contained in the air drawn in at the base, sufficient to burn any separated carbon to non-luminiferous gases. There is no doubt that even a comparatively small admixture of air destroys the illuminating power of coal gas. The observations of Silliman and Wurtz (*Sill. Amer. Jour.* [2], xlviii., 40), show that on mixing coal gas, of ordinary composition, with a fourth of its volume of air, its illuminating power is diminished by nearly 85 per cent.; hence it does not seem remarkable that the mixture burning at the mouth of the Bunsen lamp, which contains from 60 to 70 per cent. of air, should give a non-luminous flame. How, then, is the luminosity destroyed? It is easy to show that the oxygen is not necessarily the true cause; indeed, the effect is much more to be attributed to the nitrogen. The Bunsen lamp before you (fig. 3) is burning with the luminous flame which is observed when the entrance of air at the bottom is stopped; into one of these holes is screwed a small tube connected with a gasholder containing nitrogen; the other hole is closed by the cap; when I allow the nitrogen to pass into the burner and mix with the issuing gas, you notice that the luminosity rapidly diminishes, and is eventually destroyed; the flame now acquires an appearance very similar to that of the normal Bunsen flame. Knapp, to whom we owe this remarkable observation, has shown that any different gas, as carbon dioxide or hydrochloric acid, will produce exactly the same result. Indeed, if I connect the tube inserted into the air-hole with this little boiler from which steam is issuing, I shall be able to destroy the luminosity in the same manner (fig. 4). The most obvious deduction from these experiments is that the non-luminosity of the Bunsen lamp is due to the dilution of the coal gas. This result would seem to afford support to Dr. Frankland's hypothesis of the cause of luminosity in flames; on the other hand, it may be supposed that the simple extension of the luminiferous material over a sufficiently wide area, whereby it meets with a relatively greater supply of oxygen, is an adequate explanation.

The admixture of a large quantity of an indifferent gas with the coal gas will, of necessity, influence the temperature of the burning mixture, and such a reduction of temperature must, doubtless, have an effect on the illuminating power of the flame. Many years ago, Dr. Frankland proved that a mixture of marsh gas and air, which, under ordinary circumstances, gave a flame almost destitute of illuminating power, on being previously heated nearly to redness, burnt with considerable luminosity; and Wibel has recently shown that the ordinary flame of the Bunsen lamp becomes luminous when the tube is heated. The lamp before you (fig. 5) has its brass tube replaced by one of platinum; you notice, as I heat the sides of the tube with a blow-pipe flame, the Bunsen flame becomes gradually luminous; it now resembles the flame we obtained by cutting off the air supply at the base. On extinguishing the blow-pipe flame, and directing a current of cold air from the bellows on the tube, you observe that the luminosity rapidly diminishes; the flame has now recovered its normal appearance. If we repeat this operation with a burner which, as in a previous experiment, we can feed with nitrogen instead of air, precisely the

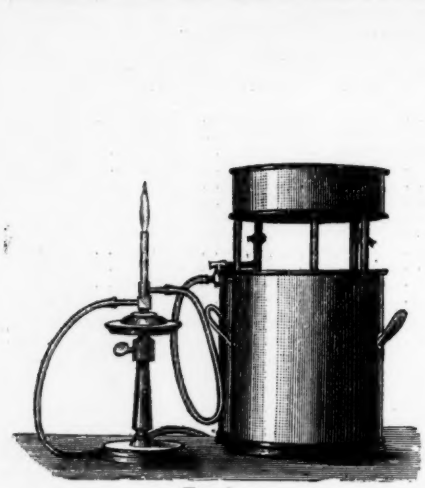


FIG. 3.

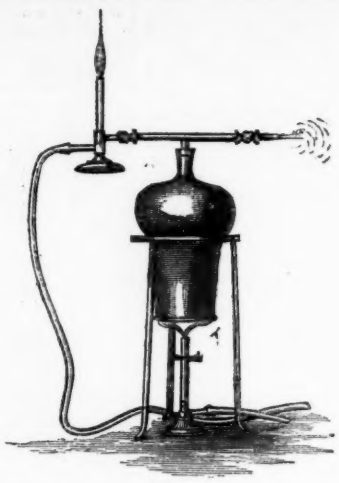


FIG. 4.

FIG. 5.

same result follows. By a slight modification of this arrangement, it can be shown that when either gas is heated singly the same effect is observed, and Heumann has proved that the phenomenon is not due to a permanent alteration in the composition of the coal gas by the preliminary heating, nor to a diminished supply of air in consequence of expansion. The conclusion is, in fact, irresistible, that the luminosity of the flame in these experiments is due to the added heat alone. The observations of Wibel and Heumann are instructive in their bearing on the hypothesis that the luminosity of a flame is related to the density of the gases or vapours which compose it; although by heating the mixed gases we diminish their density, we nevertheless increase their luminosity. Dr. Frankland has shown us that hydrogen or carbon monoxide, when burned with oxygen, under a pressure of from 15 to 20 atmospheres, yields a luminous flame. Would it not appear, in the light of the experiments we have just made, that the luminosity is due as much, if not more, to the heat which, under ordinary circumstances, is lost by the expansion of the gases, as to the density of the gases *per se*? To what, then, is the small luminosity of the Bunsen flame, as compared with that of the ordinary flame, due? To the diluting action of the gases, or to their cooling action? Not to the cooling action solely, for that would imply that the ordinary Bunsen flame has a lower temperature than the luminous flame, which we know is not the case. The feeble luminosity of the Bunsen flame is, in fact, due to a number of causes; we have, first, a rapid oxidation of luminiferous material, to gases of feeble illuminating power, by the oxygen in the admixed air; in the second place, we have the presence of diluting gases, which of themselves reduce the illuminating power; and, thirdly, we have heat withdrawn by the indifferent gases, as nitrogen, and the products of combustion, carbon dioxide, and water. We cannot say that the loss of luminosity is due to any one of these causes acting singly. A flame of mixed coal gas and air has a higher temperature than that of the undiluted coal gas, but it requires a still higher temperature, in order that a separation of carbon shall occur. The heat given to the gases by raising the temperature of the tube through which they pass is sufficient, when added to that of the combustion, to make the burning mixture luminous.

We have thus traced the mixture of coal gas and air up the tube, and we have followed its changes during the process of its conversion into its ultimate products. But as we proceed to lower the flame we may notice something of interest. When the flame is very small it will be seen that it does not immediately rest upon the end of the tube. This fact was first observed by Blochmann. The distance between the flame and tube is ordinarily not very large; but by mixing the coal gas with an inert gas, such as nitrogen, it may be greatly increased. If we repeat the experiment of diluting the coal gas with nitrogen, you will observe that we can separate the flame and tube by several millimètres. This phenomenon is probably due to two causes—namely, to the cooling action exerted by the tube (for if the tube be heated the space diminishes), and to the fact that the velocity of ignition of the mixture is much less than the rate at which the gas issues. Indeed, the cooling effect of the burner may be partly due to its action in lowering the temperature of the gases, and thus diminishing the velocity of the propagation of ignition.

Every-day experience tells us that when the flame is small there is great risk that the least draught of air, by interfering with the flow of gas up the tube, or by mixing with the gas in sufficient amount to create an explosive mixture issuing at a less rate than that of its propagation of combustion, may cause the flame to retreat down the tube and burn at the bottom, with the production of disagreeably smelling gases arising from imperfect combustion. The nature of the gases thus formed within the tube has been recently studied by Blochmann, whose results are seen in Table VI. (*Ann. der. Chem. und Pharm.* 173, 180).

TABLE VI.

	Gaseous Mixture. Before the Combustion.		After the Combustion.
H	19·91	...	9·14
CH_4	14·82	...	13·49
CO	2·26	...	4·64
C_2H_2	—	...	0·75
C_2H_4	1·57	...	0·63
C_4H_8	1·20	...	0·26
N	46·54	...	46·54
O	12·25	...	—
CO_2	0·45	...	3·02
H_2O	1·00	...	17·33
	100·00	...	95·80
Contraction	—	...	4·20

When the flame burns at the bottom, a very much smaller quantity of air passes into the tube; in the case cited, 58·9 volumes of air were mixed with 41·6 volumes of gas. We notice, on comparing the composition of the gas before burning with that remaining after partial combustion, that the proportion of marsh gas is very slightly diminished, whereas about half the hydrogen has disappeared, and with the decrease of the hydrogen we have a proportionate increase in the amount of water vapour. We notice, too, a decrease in the amount of hydrocarbons of the ethene series, and the existence of acetylene derived from their decomposition in the partially burnt gases. We also observe that the amount of carbon monoxide is more than doubled. To the carbon monoxide and acetylene is due the pernicious effect of this partially consumed gas. We notice, too, that all the free oxygen has disappeared, as, indeed, is to be expected; it is easy to demonstrate its non-existence in the gases issuing from the tube by simply holding a lucifer match over the end. You observe that the paste on the match melts as I hold it in the tube of the lamp down which the flame has retreated, but it is not ignited; on bringing the match into the free air it at once inflames.

MANCHESTER WATER SUPPLY.

THE THIRLMERE WATER SCHEME.

At the Meeting of the Manchester City Council on Wednesday last—the MAYOR (Alderman Heywood) presiding,

The following report was submitted by the Water-Works Committee:—

Your committee now bring before the council for consideration one of the most important subjects which for a long time past has engaged their attention, relating, first, to the means now possessed for a supply of water; second, the necessity for obtaining powers to enable the corporation to meet the constantly increasing demands; and, third, the steps to be taken for the purpose of obtaining the additional quantity which in the course of a few years will be certainly required by the inhabitants of the city and the surrounding districts now dependent upon the corporation.

It will readily be believed that this important subject has for years past engaged the constant and anxious attention of your committee, and this fact will at any rate be made manifest by the information which your committee have now to lay before the council.

It is obvious that the question which it has been incumbent upon your committee in the first instance to consider and determine was when the present means of supply will be exhausted, and the demand for water beyond such means arise.

Your committee have, of course, in relation to this vital question, been in constant communication with their able engineer, Mr. Bateman, and have from time to time received from him reports upon the subject. It is impossible, in dealing with this question, entirely to ignore suggestions which are sometimes made, to the effect that if the corporation had confined their supply of water to the citizens of Manchester, the present means would have been found to be sufficient. What the sanitary and commercial state of the district beyond and around the city would have been if such short-sighted and selfish policy had been adopted your committee will leave to the intelligent determination of the council. Strong and unanswerable as the arguments which are only hinted at may be, your committee may confidently add that a careful examination of the accounts of receipts and expenditure in this department, from time to time presented to the council, will conclusively prove that upon other and distinct grounds, and even in a purely selfish and monetary point of view, the wise and liberal policy hitherto adopted by the corporation has been strikingly satisfactory and successful, and has in the result enabled your committee to continue to give to the inhabitants of the city, at a moderate price, an unrestricted supply of the purest water for domestic, sanitary, and trading purposes.

In the appendices submitted, full information will be found as to the scheme for obtaining the water required from the lake Thirlmere, in the county of Cumberland, which your committee unanimously recommend the council to approve of and to adopt, and which your committee believe may—notwithstanding the large expenditure ultimately involved—be carried out without increasing the charges imposed upon the city in connexion with this department.

The cost to the corporation of the water obtained from Longdendale, exclusive of the cost of distribution, has been about £90,000 per million gallons per day; and the cost of the proposed supply from Thirlmere will vary from about £100,000 to £110,000 per million gallons per day for the first 20 million gallons daily, and to about £60,000 per million gallons per day when 50 million gallons of water per day may be required.

Your committee have been in communication with the landowners and other parties interested, with a view of making, where practicable, such arrangements as would remove any disposition to offer opposition, in Parliament or otherwise, to the scheme of the corporation; and although it is obviously inexpedient at the present time to enter into details, your committee have satisfaction in being able to state that they have been generally met in the most friendly spirit, and that they have every reason to believe that serious opposition in Parliament may be avoided. Your committee have, however, not done any act or taken any step but such as has been in their opinion absolutely imperative, prior to the scheme becoming publicly known.

In confirmation of the statement made to that effect in the report of the engineer, your committee may add that, in their opinion, there will be no injurious or undesirable interference of any kind, by the carrying out of the works proposed, with the picturesque and romantic scenery by which the Thirlmere Lake is surrounded; and that, upon the contrary, the beauty of the lake will be rather enhanced than otherwise, whilst the facilities for enjoyment to tourists and others, attracted by the loveliness of the scenery to this district, will, as the consequence of roads which will necessarily be required in connexion with the works of the corporation, be considerably increased.

Your committee have ventured to authorize preliminary steps to be taken to enable, if so determined, application to be made to Parliament during the next session for powers to carry out the scheme which is now with great confidence and entire unanimity recommended by your committee for the approval and adoption of the council.

The reports of Mr. Bateman, C.E., contained in the appendices, are subjoined. In the first, dated Feb. 18, 1875, he said:

I have from time to time considered it my duty to report to you the progressive increase in the consumption of water, the means at your disposal for meeting the demand, and the necessity of providing beforehand for the wants of the great community which is wholly dependent for its supply of water upon the water-works of Manchester. Thus in my report to you dated the 6th of October last I state: "It is of importance to observe that the quantity of water now required is constantly upon the increase. In 1855 the total quantity supplied was, in round numbers, 8 million gallons per day. In 1865, ten years subsequently, it was upwards of 11 millions, and during the summer of the present year (1874) it has been equal to nearly 18 million gallons per day on the average, having in one week amounted to nearly 21 million gallons per day. The quantity of water used per head, taking that as the unit of measurement for all purposes, is constantly on the increase." The average daily consumption throughout the year 1874 was 16,713,957 gallons. The utmost quantity which you can safely calculate upon

obtaining in extreme dry seasons from the Longdendale district, even with the aid of the reservoirs you are proposing to construct at Denton, is only from 24 to 25 million gallons per day. This is but 7 million gallons per day more than is now delivered, and if the annual increase goes on as it has done, but six or seven years will elapse before the demand will exceed the means of supply. In any new works you should go for sufficient for the next 30 or 50 years; and if you have to go—as you must—to any great distance, you should contemplate the possibility of requiring for the district within your limits of supply 40 or 50 million gallons, or even more, per day. There is nothing left in the hills from which you have hitherto gathered your supplies, nor in any district near at hand, and the only sources from which you can obtain the water you want are those contained in the lakes or mountainous districts of the north of Lancashire, Westmoreland, and Cumberland. I have long been impressed with the conviction that, sooner or later, the rapidly increasing population of the manufacturing districts of Lancashire and Yorkshire must of necessity resort to this part of the country, where the rainfall is excessive, and the uses to which the water can be locally applied small and insignificant. It is satisfactory to know that, owing to the judicious management which has always characterized your department, the very moderate rates which are now paid for water will produce a revenue which will in all probability meet the interest of the annual outlay until the completion of any works which may be determined upon, including the finishing of those in Longdendale, and the construction of the projected reservoirs at Denton, to the extent to which you may think it desirable to make them.

In the second, dated June 22, 1875, Mr. Bateman said:

The more important points to which I wish to draw your attention are facts which have been made clearly apparent since the date of my report. Amongst them are the following:—The demand for water, both in and out of the city, is going on at a rate three times as fast as the increase in population. In 1856 the average rate of consumption per head of the then population, including water for all purposes, was 14¼ gallons per head per day. It is now, in consequence of the large demand for trade and other requirements, 22 gallons per head per day, being an increase of nearly 50 per cent. in 18 years. The revenue is also increasing very largely, and in a steady manner. The increase has averaged £6000 per annum during the past five years, having in that time amounted to a total of £30,599 9s. 5d. from the supply for domestic and trade purposes both within and beyond the city. Of this sum, £21,542 19s. 11d., or more than two-thirds, have come from the districts outside the city. The rate of increase during the past five years in the domestic and trade supplies, both within and beyond the city, is as follows:—Domestic supply from 1869 to 1874: within the city, 14·2 per cent.; beyond the city, 52·5 per cent. Trade supply for the same period: Within the city, 15 per cent.; beyond the city, 39·8 per cent. The foregoing facts show that the great increase, both for domestic and trade supply, is taking place outside the city, and it is those districts which not only help the corporation to pay all the costs of the undertaking, but it is there the surplus profit is made. The population of the districts immediately adjoining Manchester, and indeed for some distance all round, must be considered as inhabitants of Manchester, probably carrying on their trade in the city, and living beyond its precincts. They cannot be looked upon as aliens, nor should their interests be neglected, when it is seen that the increase in domestic supply outside the city is nearly four times as great as it is within the city, and in the trade supply nearly three times as great.

In the next, dated June 22, 1876, Mr. Bateman said:

In addition to Ullswater and Haweswater there is only one other lake whose elevation above the sea is sufficient to give a supply by gravitation; this is Thirlmere, and it has been suggested by your chairman (Mr. Alderman Grave) that all the water which Manchester may require may be obtained from thence at less cost than from any other source. I have accordingly, as instructed, investigated the question, and visited the ground in company with Mr. Hill, C.E. The respective elevations of the three lakes are as follow—Ordnance measure: Ullswater 477 feet, Thirlmere 533 feet, Haweswater 695 feet. Thus Thirlmere is 56 feet higher than Ullswater, lies at about the same distance, and is clearly high enough for the supply of water by gravitation to Manchester and its neighbourhood. The area of the lake at its present level is about 335 acres, and the drainage ground from which water may be collected is about 11,000 acres. This ground is exceedingly steep, yields beautiful water, and lies close to, if not in the heart of, the heaviest rainfall. In the same year in which 65½ inches fell at Haweswater, 81½ inches fell at Thirlmere, being about 30 per cent. greater than the rain at Haweswater. The outlet of the lake is in a narrow rocky ravine, the rocks being of Silurian formation, and perfectly watertight. It would be easy to raise an embankment or wall at this point to any required height, but about 35 feet above the surface of the lake will be sufficient to guarantee a supply of upwards of 40 million gallons per day to the city of Manchester, after allowing for loss by absorption and evaporation and full compensation to the river. The area of the lake, if so raised, would be increased from 335 acres to about 700 acres, and would form a reservoir containing about 800 million cubic feet The country from Ambleside to the head of Rydal Water is rough and rugged; but the aqueduct would pass far above all residential property, and presents no difficulty either of an engineering character, or of interference with ornamental land. The town of Ambleside, and the good houses which now exist and are constantly rising on the banks of Grasmere, Rydal Water, and Windermere, may be very conveniently supplied from the aqueduct, which would run above them; and the various mountain streams which would be passed in this part of the aqueduct might, by arrangement, be taken into the aqueduct in times of freshets, and the daily quantity thereby increased. One feature commends this lake especially to your consideration. Instead of a tunnel 8¼ miles long from Ullswater, and above 1000 feet below the summit of Kirkstone Pass, a tunnel from Thirlmere would be only 3 miles in length, and but 270 feet at the greatest depth below the surface of the ground at Dunmail Raise. It would pass wholly through rocks of the Silurian formation, very similar to, but not so hard as, the first 10 or 11 miles of the Loch Katrine aqueduct. The difference in cost betwixt Ullswater on the one hand and Thirlmere on the other, will be about £170,000 in favour of Thirlmere, and the time required for the execution of the work may be reduced, if desired, from seven to five years, or probably less. Taking the time necessary for an application to Parliament and the preparation of working drawings at two years in either case, Ullswater might be reached in nine years from the present time, and Thirlmere in seven years. This latter period is quite as long as the Longdendale supply can be expected to last. Supposing the aqueduct were constructed on a scale large enough to convey 50 million gallons per day, the extra cost would be about £100,000, still leaving a saving in favour of Thirlmere of £70,000. Although a large tract of land would be submerged by raising the lake 35 feet as proposed, there would be little residential injury or damage to ornamental property, and compensation in water would get rid of all the claims of the small mills on the river below. It thus appears, on full consideration, that Thirlmere deserves your special attention as an independent source of supply to Manchester, and I therefore recommend its adoption.

A table giving the rainfall in the lake district showed that the average rainfall in eight years—from 1868 to 1875—was 93·09 inches in the Thirlmere district.

On the 20th of April, 1877, Mr. Bateman made the following report:—

The gross outlay to be incurred by the corporation for the first instalment of the water from Thirlmere, exclusive of land, will probably be about £1,700,000, for which the works will be constructed, so far as the built aqueduct and tunnels go, and the collection and impounding of water at Thirlmere for 50 million gallons per day, and for cast-iron pipes or inverted syphons across the great rivers which have to be passed, for 10 million gallons per day. The works required are simple, and the country favourable. The total distance will be about 100 miles. The water will be taken from near the upper end of the present lake, carried under Dunmail Raise by a tunnel, and then passed above Grasmere, Rydal, and Ambleside to Troutbeck, after crossing which stream by an inverted cast-iron syphon-pipe, the conduit will enter a tunnel which will carry it beyond the residences of St. Catherine's, Elleray, and others into the open country to the south-east of the Windermere Station. The conduit or aqueduct will be kept to the hills wherever practicable, crossing the Lune about five miles above Lancaster, the Ribble about five miles above Preston, passing close under the Rivington reservoirs of the Liverpool Corporation, and after crossing the river Eagley and tunnelling under the hill near Deane Church, will terminate in a service reservoir near Bolton. The top water-level of this reservoir will be about 360 feet above the sea, or 40 feet above the existing service reservoirs at Denton, and about 60 feet above those which will probably be constructed there for the purpose of receiving the surplus water of Thirlmere for the supply of the lower portion of Manchester. From the service reservoir near Bolton (which from its being in the midst of smoke must be covered over), the water will be supplied by a pipe to Pendleton, Salford, and Manchester, to be carried along the public road, and will be conveyed to Denton by a pipe passing by Worsley, Barton, Fallowfield, and Levenshulme. The conduit from the service reservoir near Bolton to Thirlmere will be tunnelled or cut in the solid ground, and covered over, and will be constructed of a size sufficient to convey 50 million gallons in 24 hours. In crossing the rivers Darwen, Ribble, Lune, Kent, and other streams, inverted cast-iron syphon pipes will have to be laid. These will, in the first instance, as already stated, be laid equal to the passage of 10 million gallons per day, and will have to be increased in number from time to time as the demand requires. The whole of the country through which the aqueduct will pass has been carefully explored, and the line fixed with reference to economy and the avoidance of interference with residential property. Of course the estimates which have hitherto been made, and the line of conduit which has hitherto been laid out, must be considered as approximate only, subject to revision on a more careful examination of the country.

Samples of water from Thirlmere had been submitted for analysis to Professor Roscoe, Messrs. Crace-Calvert and Thomson, and Dr. E. Frankland. Mr. Roscoe's analysis gave the following results:—

	Grains per Gallon.		Parts per Million.
Total solids	1·45	..	20·71
Chlorine	0·40	..	5·71
Albuminoid ammonia	0·0049	..	0·07
Nitrogen as nitrates and nitrites	0·0247	..	0·35
Total hardness	0·5	..	—
Permanent hardness	0·5	..	—

Alderman GRAVE moved the adoption of the report, and that the committee be authorized to take the requisite steps for carrying into effect its recommendations. In doing so, he said it was estimated at first that 33 million gallons of water would be daily received from Longdendale, but, owing to the nature of the ground, the presence chiefly of porous rock by which the water was absorbed, the actual supply did not exceed 25½ millions. That, he believed, was the largest quantity that the city had received since the works were completed from Woodhead. Last week, and the preceding week, the consumption was 20,300,000 or 20,400,000 gallons per day. The committee, having regard to these facts, told the council that they were on the border-land of scarcity. Day by day that fact was forcing itself upon their attention. It had led the committee and their engineer to look out almost everywhere with a view to supplement the existing works. Thirlmere had been fixed upon, and the facts and figures contained in the report would, he felt sure, convince the council of the advisability of the scheme now recommended. Five or six years hence, when they might expect the demand for more water to become pressing, they might obtain from that new source a supply which would be adequate to their wants, and practically inexhaustible. If they did not seize the present opportunity, Manchester would find itself in a few years forestalled. They were bound to protect the commercial and manufacturing interests of Manchester, with which the water supply was so closely bound up. He defied any one to controvert the facts contained in the report, or to say where results equal to those which they anticipated could be obtained elsewhere. The total area of their gathering-ground in Cumberland would be 11,787 acres. The supply from that area would be larger than the supply from their 19,000 acres of gathering-ground in Longdendale. The rainfall was prodigious, often reaching 110 inches, and the quality of the water had been pronounced by competent analysts to be equal, if not superior, to that of Loch Katrine. For manufacturing purposes it would be found invaluable. They had it on the authority of the first water engineer of the day that from Thirlmere itself a supply of 50 million gallons per day would be derived, and that there were in the district tributary lakes and streams which would form a supplementary supply, if needed, for future generations. As a resident in the district, and having been acquainted with it all his life, he assured the council that no one would protect the beauties of Thirlmere with greater ardour than himself. He could not conceive how any one could be haunted with the idea that they meant to destroy the natural beauty of the country. That they would do so in any degree he emphatically denied, for their work would consist only of an embankment of small dimensions at the northern end of the lake, a tunnel under Dunmail Raise, and covered conduits conveying the water to Manchester. A common stone wall in the Lake country defaced its features ten thousand times more than one of their pipes, which would not be visible above ground, was likely to do. They were not wasting the money of the ratepayers. All they had ventured to do was to secure a footing in the neighbourhood, and instead of giving exorbitant prices for small quantities of land, they had not given any more than their own valuation. He knew of no watershed in the North equal to this. The natural elevation was such that water could be brought to Manchester and the highest parts of the present water-works system by gravitation. They were disturbing no one by the scheme. He did not think there were 200 people in the whole neighbourhood. They were doing the least possible injury to the least possible number of people, and at the same time they were obtaining the greatest possible advantage.

Alderman PATTESON seconded the motion.

Mr. ROWLEY admitted that the scheme could not be objected to as impracticable; but, with every confidence in the committee by whom it was recommended, he doubted the propriety of the corporation entering upon such a career of trade as they would be involved in by this scheme for the supply of places out of Manchester. He asked if a supply nearer than that at Thirlmere could not be obtained, and suggested that this might be done in the Kinder Scout district, or in the valley of the Lune. The great objection to the scheme, however, was one founded upon sentiment. The Lake district was to England what the Alps were to Europe—a playground and a recreation ground—and they should be chary about destroying any of its beauty. This scheme would greatly mar the picturesque character of the district, and would, moreover, create much opposition in the neighbourhood, as correspondence in his possession clearly indicated.

Alderman HOPKINSON said he had visited the district, and the result of his inspection supported the statements in the committee's report. One advantage in connexion with the scheme was that they would have a duplicate system, and would not be dependent upon one source only for their supply. Then he believed that by raising the level of the lake its appearance would be rather improved than otherwise. They would get a bolder shore, and an embankment might be made without interfering at all with the beauty of the district. It had been said that water could be had elsewhere, and the valley of the Lune had been suggested, but in that direction they would have to go quite as far as Thirlmere. The conclusion he had come to was this, that, through the great elevation of the lake, the prodigious rainfall, the favourable nature of the geological strata, which were impervious, the non-residential character of the population, the comparative purity of the water, the security they had against pollution by being proprietors of the land within the gathering area, and especially on account of the capacity for further extension, the scheme was one of great value. This was at once the nearest, purest, and cheapest water supply which they could obtain for the future wants of Manchester and neighbourhood.

Alderman KING said the question arose in his mind whether it would not be advisable to put some restriction upon the amount of water supplied for trade purposes. This objection would be raised by the opponents of the scheme, who would say, "You do not want this water for the absolute necessities of Manchester and its neighbourhood, but as a means of trade." And, even supposing they proved their case for the necessity of the increased supply, the next question was, "Could they not get a supply from a source which would not raise sentimental objections?" Mr. Bateman seemed to recommend this scheme in a mild way. In his report of the Ullswater scheme for Liverpool and Manchester Mr. Bateman said that 80 million gallons of water could be supplied without any difficulty from Ullswater—40 million gallons for Manchester, and 40 millions for Liverpool. If that was the case, he held that 80 million gallons could

be obtained for Manchester, and he believed the increased cost over the Thirlmere scheme was only £70,000. If they got their water from Ullswater they would not in any way interfere with the scenery, whereas at Thirlmere, when the lake was not full, they would have a large portion of muddy shore which would disfigure the scene. He did not see how they were going to get more water from Thirlmere than they obtained now from Woodhead, and he was convinced also that they must prepare themselves for a long and heavy parliamentary contest. He thought, therefore, it would be better to wait until the next meeting of the council, and instruct the committee in the meantime to obtain further information.

Alderman CURTIS believed that if they obtained power to take water from Thirlmere they would have to undertake to supply a number of towns between that place and Manchester. The increased supply was required, not for Manchester, but purely and simply for the out-districts, and if they had to undertake the responsibility of supplying new districts, they would, at some future time, have to obtain a greater supply, not for Manchester, but for other towns. If the council were, however, prepared to undertake that responsibility, he did not see that they could have a better scheme than this.

Mr. STEWART said it was a legitimate thing to circumscribe the area within which they supplied gas, seeing that gas-works were poisoning the inhabitants of the city; but the supply of water was a different thing, and he was surprised that Alderman King was desirous, on the ground of sentiment, of keeping the mountains of Cumberland open to men like himself, but did not object to the people in Manchester being poisoned by having large gas-works in their midst. The prosperity of Manchester depended upon the development of the surrounding districts, and in order to further that development, they were bound to supply these districts with water.

Alderman BENNETT said if they curtailed the water supply to the industrial community, of which Manchester was the centre, they would injure the prosperity of the city. In the case of the Ullswater scheme, the total cost would have been £4,000,000, the share of Manchester being £2,000,000. For that expense Liverpool and Manchester would have had 80 million gallons of water per day divided between them; and yet for a less expenditure, and with far less difficulty, they could obtain a larger supply from Thirlmere.

Alderman PATTESON and Alderman GRAVE having made a few observations in support of the proposal,

The motion for the adoption of the report was put, and carried with one dissentient.

IRON AND COAL TRADES OF SHEFFIELD, SOUTH YORKSHIRE AND NORTH DERBYSHIRE.

(FROM OUR OWN CORRESPONDENT.)

The iron trade in every department remains very quiet, and, so far as can be ascertained by careful observation and thorough inquiries, there is hardly any prospect of any alteration for the better being inaugurated during the immediate future. As a natural consequence of this state of things, everything is in a quiet condition, and the business that is being currently transacted is simply on a hand-to-mouth scale. There is only a moderate turnover in any branch, and producers of the finished article are everywhere limiting their purchases as much as possible. In one or two yards, it is true, there are pretty fair stocks of pig iron on hand, but for the most part these consist of hematite and other best class pigs. There is but little change in pig iron quotations, which, nominally at all events, remain at the following rates:—North Yorkshire No. 1 foundry, 44s.; No. 2 foundry, 43s.; No. 3 foundry, 41s.; No. 4 foundry, 40s.; No, 4 forge, grey, 40s.; No. 5 forge, mottled, 40s., No. 6 forge, white, 39s. 6d.; refined metal, 57s.; Kentledge, 43s.; and cinder, 37s.; Lincolnshire No. 1 foundry, 50s. to 52s. 6d.; No. 2 foundry, 47s. 6d. to 49s., and No. 3 foundry 45s. to 47s. 6d. Derbyshire foundry, 60s. to 62s.; forge, 52s. 6d. to 59s. 6d. per ton.

There is a moderately well-sustained production of pipes for gas, water, steam, and colliery purposes at the larger foundries, and a few small specifications are now out for further lots of the two former kinds. For such orders there is a very keen competition between the Yorkshire, Derbyshire, and north country houses, prices being £5 17s. 6d. to £6 5s. per ton for ordinary mains. In the coal trade there are growing signs of the bad times in all directions. Some of the colliery owners are discharging men almost every week, whilst others are reducing wages. In some cases the men have gone out on strike against this process, but their standpoints are defective, and they have no alternative but to submit to the force of circumstances. Prices remain steady, but are at a low level in all directions. House coal is at a discount, but there is a tolerably fair export—say 25,000 tons weekly—of steam coal.

THE LANCASHIRE COAL AND IRON TRADES.

(FROM OUR OWN CORRESPONDENT.)

Business in the gas coal trade of this district has been very quiet during the past week, and the strike in West Lancashire has had a very different effect upon the market to what was anticipated. Instead of causing a stiffer tone, the market is quite as weak as ever, whilst consumers, finding that the stoppage of the pits has been so little felt, are exhibiting a disposition to hold back their orders, in the expectation that when the strike is over lower prices still will be accepted. Very few gas coal contracts are, therefore, at present being given out, and the inquiries in the market are at low prices, buyers being unwilling to give more than 8s. per ton for good screened gas coal at the pit's mouth. For other descriptions of round coal there is also very little demand, and supplies are plentiful in the market, many of the colliery proprietors whose pits have been stopped having still considerable stocks on hand. Prices are weak, and there are plenty of sellers, who are pushing for orders at quite as low rates as were ruling before the strike, good Arley coal at the pit's mouth being offered at 10s. to 10s. 6d. per ton, and Pemberton four-feet at 8s. to 8s. 6d. per ton, whilst for common coal it is difficult to get more than 7s. per ton at the pit. Engine classes of fuel, however, continue in good demand, and for slack sellers are able to command a slight advance upon last month's rates. Good burgy at the pit is quoted at 5s. 6d. to 6s., and good slack 4s. 6d. to 5s. 6d. per ton.

The shipping trade is dull, Lancashire colliery proprietors being able to secure but very few orders in the face of the low rates ruling in other districts.

The men in one of the best Lancashire districts have resumed work on the masters terms, and it is thought probable the strike generally will collapse before long, as the non-union men have received no support.

The iron trade is very dull, and local makers of pig iron are put quite out of the market by the extremely low prices at which north country iron is offered in this district. The manufactured iron trade also shows no improvement, many of the works being wholly or partially closed for want of orders, and although the current market rates are without change, there is a great deal of underselling to secure orders.

THE COAL AND GENERAL TRADE OF THE NORTH.

(FROM OUR OWN CORRESPONDENT.)

It is a remarkable thing, notwithstanding the Durham gas coal trade is reported to be dull and flat, and the household trade moderate, 36,000 chaldrons of Durham coals, mostly gas and households, were shipped from the Tyne Dock last week, which is a large exportation even in very active times. The second-class steam coal trade is falling off materially. There is a satisfactory inquiry for the better qualities of steam, with good shipments abroad. Most of the best steam collieries have a week's work on hand. Some rather more. Prices remain nominally the same. Best gas may be quoted at from 7s. to 8s. 6d.; seconds from 6s. to 6s. 6d.; house coals, 11s. to 12s.; best seconds, 9s. 6d. to 10s. per ton. The collieries work unequally. They are regulated every week by the orders to hand for the moment. Some of the second-class Northumberland collieries were off a day or two last week.

The supply of steam tonnage in the coal ports continues to be quite in excess of the demand. Freights, consequently, have a tendency downwards. There is a limited number of small sailing ships in port, but as nearly every one seems to be fully supplied with coals in the byeports of the south, they are not very much in request, and rates to the east coast, the Channel, and France are unchanged. The principal shipments of coals from the north-east ports of England are by steamer, and a good deal seems to be sent up on consignment to be sold in the open market. The goods trade was somewhat better last week, but it was purely accidental that it was so, as shipments had been retarded in the previous week through the annual holidays held on Tyneside. The principal shipments of goods consist of fire-bricks and articles of manufacture of that description. There is not much iron going abroad, and the chemical trade is without animation. What little business is done in the chemical market seems to be forced. The iron trade of Middlesbrough, and the Cleveland district generally, is no way improved. There is little demand either for home or for abroad, and the phrase might almost be stereotyped, "What business is doing is from hand to mouth."

TRADE NOTES FROM SCOTLAND.

(FROM OUR OWN CORRESPONDENT.)

Perhaps the most important news item which I have to mention this week is one which refers to the Aiken-Young process, and therefore I give it the place of honour. It is to the effect that the Sub-committee on Works of the Glasgow Corporation Gas Committee have recently authorized Mr. Foulis, the general manager and engineer, to fit up at the Dalmarnock Gas-Works the necessary apparatus for testing the process for making gas on the most complete scale. Mr. Foulis had previously reported to them in favour of such a measure being undertaken, in doing which he had doubtless been greatly influenced by the character of Dr. Wallace's report upon the process, a summary of which was given in a recent issue of the JOURNAL. The decision just come to by the Glasgow Corporation gas authorities will doubtless have an important influence in the discussion of the process at the forthcoming annual meeting of the North British Association of Gas Managers to be held at Stirling.

At last Thursday's monthly meeting of the Town Council of Glasgow, the subject of a meter-testing house was brought up for consideration in the Gas Committee's minutes, and it is probable that an establishment of a very complete description for the testing and repair of meters, testing of gas, &c., will be erected in a central part of the city. For a number of years those operations have been carried on in a building in Alston Street, which is very soon to be demolished on account of the site being required for the Caledonian Railway Company's new central station.

On Monday, the 2nd inst., a special meeting of the Burgh Commissioners of Alloa was held, for the purpose of considering what further steps it would be necessary to take for the acquisition of the Alloa Gas-Works. The clerk intimated that he had served a notice on the gas company to say that the commissioners had adopted the Burghs Gas Supply (Scotland) Act, 1876, and that they were willing to treat for the purchase of the works and everything connected with the undertaking. He had been officially informed that the company were willing to sell the works by arbitration, and they had appointed Mr. W. P. Wilson, of London, as their arbiter. He (the clerk) had written to Mr. Foulis, of Glasgow, with the view of getting him to be the arbiter for the commissioners. A deputation of the commissioners saw Mr. Foulis in Glasgow on the following day, and at a special meeting of the commissioners, held on Wednesday evening, it was reported that Mr. Foulis had agreed to act as their arbiter, and that they had left him fully posted up in the whole matter. It will thus be seen that Alloa is now in advance of Dumfries and Johnstone as regards the acquisition of the gas undertaking.

At the annual meeting of the Kilwinning Gas Company, held last Tuesday, a dividend of 8s. on the original £5 shares was declared. Afterwards it was resolved that a plebiscite of the consumers be taken on the question as to whether or not the company should take charge of lighting the streets with gas during the winter. Hitherto there have been no public street-lamps in the town, which is lighted during the dark nights only with the glare of the blast furnaces belonging to the Eglinton Iron Company.

The annual meeting of the Banff Gaslight Company was held on Monday, the 2nd inst., when it was resolved to reduce the price of gas from 7s. 6d. to 7s. 1d. per 1000 cubic feet, and to allow 5 per cent. to consumers whose annual accounts amount to £15. This makes the price equal to about 6s. 10d. per 1000 feet.

On Monday, the 2nd inst., the meeting of the Brechin Gaslight Company was held. From the directors report it appeared that the income of the company during the past year had been about £215 less than that of the preceding year, which was accounted for by the reduction of 5d. per 1000 cubic feet made on the price of gas twelve months ago. The consumption of gas during the past year was nearly 200,000 cubic feet in excess of that of the previous year. A dividend at the rate of 7½ per cent. on the capital stock, as now increased, was declared, and the balance of the year's profit was ordered to be carried to the credit of the contingent-fund. The manager having reported that the cost of coals for the ensuing year was likely to be at least £100 more than last year, the price of gas was continued at the same rate—namely, 5s. per 1000 cubic feet.

On the same day the annual meeting of the Alyth Gas Company was held. The income for the year was £892 6s. 7d., and the expenditure was larger than usual, owing to the repair and improvement of the works necessitated by the fire which occurred last season, and the loss on coal from the same disaster. A dividend of 8 per cent. was declared, which amounted to £200. The price of gas was reduced 10d. per 1000 cubic feet, which will thus stand at 6s. 8d. per 1000 feet after October next.

The Wemyss and Buckhaven Gas Company's annual meeting was held on Thursday evening, when the secretary, Mr. Ness, submitted his annual statement, which was considered very satisfactory. The price of gas will still remain at 7s. 6d. per 1000 cubic feet, which certainly seems rather high for a town that is so near to the rich cannel of the Fifeshire coalfield. After meeting all liabilities, a dividend of 6 per cent. was declared.

The annual meeting of the Anstruther and Cellardyke Gas Company was held on Wednesday evening. On the recommendation of the directors, it was agreed to reduce the price of gas from 6s. 8d. to 5s. 10d. per 1000 cubic feet, to declare the usual dividend of 8 per cent., and to add £100 to the contingent-fund.

Both the Edinburgh and the Edinburgh and Leith Gas Companies have

announced a reduction in the price of gas to 4s. 4d. per 1000 cubic feet, the reduction to take effect on the accounts for the current quarter, and the discounts and meter-rents to remain as at present.

The shareholders of the Bothwell and Uddingston Gas Company held their annual meeting last Monday evening, when, on the recommendation of the directors, it was resolved to declare a dividend of 7½ per cent. on the paid-up capital of £7000. The balance-sheet showed that the affairs of the company were in a very prosperous condition.

On Wednesday last the annual general meeting of the Ayr Gas Company was held. The directors report was submitted, and, in moving its adoption, the chairman said that during the past year they had heard complaints about the impurity of the gas supplied by the company, but it was to be remembered that the works were opened so long ago as 1826, and that many of the pipes then, or shortly afterwards, laid to connect the house services with the mains, and also the house services themselves, were still in use. He had no doubt that the impurity of the gas in certain cases was due to this cause. Where the pipes were new, the gas was perfectly pure. Various alterations had been made at the works, and others were in progress, including the erection of four additional retorts, a new purifier, and the construction of a new tar-tank. The average illuminating power of the gas made throughout the year had been 27·87 standard candles. It was recommended to reduce the price of the gas from 5s. 10d. to 5s. 5d. per 1000 cubic feet, as from the commencement of the quarter now current, and to declare a dividend at the same rate as formerly—namely, 6 per cent., free of income-tax. The report was adopted, and the retiring directors were re-elected.

The remainder of my gas and the water notes must be postponed till next week.

Iron and coal remain very much as they were last week, both in price and demand.

Reduction in the Price of Gas.—The directors of the York United Gas-light Company have announced a reduction in the price of gas from 3s. to 2s. 6d., to take effect from the commencement of the current quarter.

Sale of Provincial Gas Shares.—On the 29th ult. some shares in the Derby Gas Company were offered for sale by auction, when six original £25 ten per cent. shares, fully paid up, realized £59 each; and six new £25 seven per cent. shares, with £18 15s. paid up, realized £33 15s. each.

Quality of the Birmingham Gas.—From the report of Mr. T. Jackson, the corporation gas examiner, it appears that during the month of June, at the four gas-making stations, 17 examinations were made of the illuminating power of the gas supplied to the borough. The maximum light in sperm candles was 17·88; minimum, 16·61; average, 17·16. The Parliamentary standard is 15 candles, with Sugg's No. 1 "London" burner.

Taunton Water-Works.—At a meeting of the Taunton Town Council, on the 3rd inst., a report was submitted by the Finance Committee, recommending that application should at once be made to the Loan Commissioners to advance £20,000 for the purchase of the water-works, and the sanction of the Local Government Board be obtained to a further loan of £10,000, to purchase water rights and extend the water-works. The council adopted the recommendations.

Hinckley Gas Company.—The fifth annual meeting was held on the 28th ult. The directors report stated that "the contracts for coal for the current year have been placed on very satisfactory terms, which will enable the board to reduce the price of gas 5d. per 1000 feet, the reduction to take effect on the quarter ending the 29th of September next. The net profit of the year amounts to £1323, which will admit of a dividend of 10s. 6d. per share, equal to 7½ per cent., carrying forward a balance of £273 to next year. The amount of the reserve-fund is £241."

Darlington Corporation Gas Supply.—At the meeting of the Darlington Town Council, on the 5th inst., it was stated by Alderman Kitching that the gas made for the half year ending the 21st of June was 61,823,800 cubic feet, against 58,839,200 cubic feet for the half year ending the 21st of June, 1877. This showed an increase for the last half year of 2,984,600 feet. The coal for the half year ending the 21st of June this year was 6273 tons 2 cwt. In the half year ending the 21st of June, 1876, there was consumed 2620 tons—an increase for the half year of 652 tons 19 cwt. The average quantity of gas obtained per ton for the last half year was 9954 cubic feet.

Death of Mr. S. H. Warren.—It is with unfeigned sorrow we record the death of Mr. Warren, the late manager of the Crewe Gas-Works. Nine months ago he left Crewe to accept a situation of a much more lucrative character at Pernambuco, and on Thursday morning, the 21st ult., the sad news arrived in Crewe that he was dead. It is not too much to say that the intelligence caused universal sorrow. Mr. Warren was not, we believe, more than 24 years of age, but he had made his mark wherever he had gone. His death resulted from yellow fever. For two or three nights he had been engaged in laying mains across a bridge, and fever supervening upon great prostration caused his untimely end.—*Crewe and Nantwich Chronicle.*

Southampton Water Supply.—At the meeting of the Southampton Town Council, on the 4th inst., the Finance Committee brought up a report in which they recommended that a reduction should take place in the charge for water supplied by meter from 9d. to 6d. per 1000 gallons. It was stated that the proposal would make a reduction in the receipts of £800 a year, going upon the basis of the present supply, but it was possible that the quantity consumed would be considerably increased through the reduction in the charge for the water. Notwithstanding this reduction, the sanitary rate would be 2d. less than last year, and less than it had been for the last 13 years. The committee considered that, 2½d. being the actual cost for 1000 gallons of water, a profit of 3½d. was sufficient. The report was adopted.

Alfreton Water-Works.—A farmer, named Ford, was summoned on Wednesday last before the magistrates, by the Belper Union Rural Sanitary Authority, for refusing to allow the engineers, &c., connected with the Alfreton Water-Works to go over his land. It appeared that two or three fields on defendant's farm are required for the water-works, and that he objected to the engineers making a survey before he received compensation, although the Public Health Act of 1875 authorized a surveyor to lay open lands for examination. The defendant informed the Bench that there had already been £20 worth of damage done to his land, and that his fences had been broken down, so that other people's cattle had got into his fields. Defendant was informed by the Bench that he would be compensated in the end for whatever damage was done to his land, and he then stated that he should offer no further opposition.

Transfer of Gas-Works to the Walsall Corporation.—At the meeting of the Walsall Town Council, on the 2nd inst., a report from the Gas Committee was read, stating that the chairman and town-clerk attended on the previous Saturday at the offices of the Birmingham Corporation, and executed all deeds, &c., necessary to transfer the portion of the Birmingham Corporation's gas plant which was in Walsall to the council. In future, therefore, gas would only be supplied in the borough by the Walsall Council, and the outlying parts of the town would at once begin to receive it at the cheaper rate. The town-clerk was authorized, pursuant to a recommendation of the Gas Committee, to raise £20,000, in one or more sums, at a rate of interest not exceeding £4 per cent., towards the cost of the new gas-works, and to direct the common seal to be affixed to a mortgage debenture or debentures accordingly.

Birkenhead Gas and Water Supply.—At the meeting of the Birkenhead Commissioners on the 3rd inst., it was stated that a letter had been received from Mr. William Callow, tendering his resignation as gas and water engineer. Mr. Henderson, in moving the confirmation of the minutes of the Gas and Water Committee, said he regretted that they were about to lose the services of their worthy and able gas and water engineer, who had been 18 years in the service of the commissioners, and during that time had not made a single enemy. Mr. Callow's resignation was still under consideration by the committee, and it was hoped that an arrangement would be come to to appoint him resident engineer, by which he would be able to render assistance to those who might succeed him. Mr. Henderson added that arrangements had been made for the supply of a better class of cannel, so that the gas in future would be purer than it had been, and the committee also expected to be in a position to make a futher reduction in the price of gas in October next.

Edinburgh and District Water Trust Accounts.—The abstract of accounts of this Trust, for the year ending May 15, 1877, shows the following items of receipt and expenditure:—Balance at May, 1876, £3502 6s. 1½d.; cash received as water-rates, £50,702 10s. 1½d.; heritable property, £157 11s. 6d.; landlord's taxes, £1 19s. 6d.; miscellaneous receipts, £336 2s. 2d.; arrears of water-rates, £1354 13s. 3½d.; making a total of £55,955 2s. 8½d. The expenditure was as follows:—Salaries, £2070 5s. 3d.; wages, £2470 1s. 8d.; repairs, £3250 15s. 3d.; feu-duties, rents, and taxes, £3382 15s. 8½d.; interest on borrowed money, £15,731 15s. 3d.; annuities, £24,530 14s.; Act of Parliament expenses, 1876, £2330 16s. 11d.; Act of Parliament expenses, 1877, £285 13s. 6d.; miscellaneous expenses, £687 3s. 1½d.; carried to sinking-fund, 1 per cent. on £87,000 mortgages under the Act of 1869, £870. Total expenditure, £55,874 7s. 9d., leaving a balance in favour of revenue of £80 14s. 11½d. The capital account shows a net balance of expenditure of £838,614 5s. 10½d.

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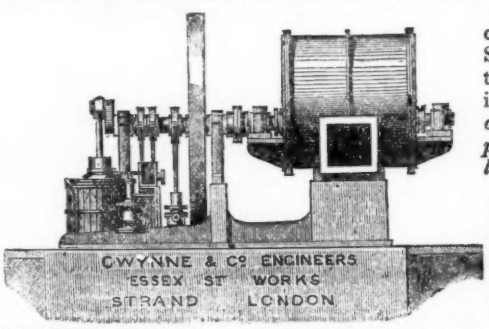

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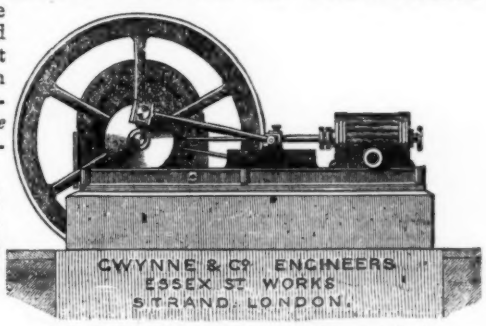

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WANTED, small Gas-Works on Lease, for 7, 14, or 21 years. Annual make from two to six millions; a per centage upon capital to be paid as rent.
Advertiser is also open to purchase small gas-works.
Address No. 381, care of Mr. King, 11, Bolt Court, FLEET STREET, E.C.

WANTED, by a Young Man who has served his apprenticeship to a Gas Engineer, a situation as MANAGER of a small Gas-Works, or to act as Assistant to the Engineer of a large Works; has had good practical experience, and can be strongly recommended.
Address No. 382, care of Mr. King, 11, Bolt Court, FLEET STREET, E.C.

WANTED, by a Working Manager of a Gas-Work, a SITUATION. Can do main and service laying, meter-fixing, setting of retorts, clay or iron, on an improved principle, inside or outside fittings of any description. Twelve years testimonials. Abroad preferred.
Address No. 380, care of Mr. King, 11, Bolt Court, FLEET STREET, E.C.

WANTED, for two small Gas-Works, each producing about 3,000,000 cubic feet per annum, two WORKING MANAGERS, who can lay mains and services, fix and attend to meters, &c. House, fire, and light free.
Apply, stating wages required and particulars of former employment, to Mr. JOHN EUNSON, Gas-Works, NORTHAMPTON.

TO GAS ENGINEERS.

WANTED, by a Provincial Gas Com- pany, a thoroughly competent GAS ENGINEER to take the charge of a Gas-Works in the South of England, where the make of gas is about 140 million cubic feet per annum.
Applications, with particulars of present engagement, references, and amount of salary required, may be addressed in first instance to No. 383, care of Mr. King, 11, Bolt Court, FLEET STREET, E.C.

THE RATING OF GAS AND WATER WORKS.

A Gentleman of experience in the Rating of Properties of Public Companies is willing to undertake, in the interests of Companies, the Valuation of Gas and Water Works for Rating purposes.
Address, in first instance, No. 367, care of Mr. King, 11, Bolt Court, FLEET STREET, E.C.

THE Malvern Local Board require an ASSISTANT to the Surveyor and Gas Manager. Salary 35s. per week.
Full information respecting the duties may be obtained of the Surveyor and Gas Manager, Mr. J. E. Palmer, Local Board Office, Malvern.
Applications, with testimonials, to be sent to the undersigned on or before Monday, the 23rd day of July inst.
By order of the Board,
WM. WILKES CAWLEY, Clerk.
Local Board Office, Malvern, July, 1877.

FOR SALE—A Set of Four Purifiers, 8 ft. by 6 ft., with covers, grids, centre-valve, and 6-in. connexions complete.
Apply to J. GILL, Gas-Works, BRIDGNORTH.

FOR SALE—A Patent Purifier and Valve-Box, with 4-in. connexions, suitable for a small Gas-Works. Enlargement of works has rendered above unnecessary.
Apply to the SECRETARY of the Kirkby Stephen Gas-Works, WESTMORELAND.

READING GAS COMPANY.

FOR SALE, as they now stand, and at any reasonable price, as the ground upon which they stand is wanted, four 12-ft. square Cast-Iron PURIFIERS, with centre-valve and connexions, grids, tee bars, &c., complete.
Apply to Mr. E. BAKER, Engineer, Gas-Works, READING.

FOR SALE—One Exhauster by Jones, of Birmingham, capacity 25,000 feet per hour, with bye-pass, 12-in. inlet and outlet pipes and valves complete, in first-class working condition, price £40; also one Exhauster Regulator, with chain and weights complete, price £5.
Apply to CLAPHAM BROS., Ironfounders, &c., Keighley, YORKS.

TO BE DISPOSED OF—A Gas-Meter and GAS-COOKING APPARATUS MANUFACTORY (excellent premises) to which a Heavy Ironmongery trade might be added. Proprietor retiring.
Address R., Mr. Fenton, 1, Commercial Street, LEEDS.

GASHOLDER FOR SALE.

ONE Telescopic Gasholder, 70 feet by 20 feet, complete, with cast-iron tank, columns, girders, and inlet and outlet pipes, valves, &c., of modern construction. In first-class condition, and made by Messrs. Piggott and Co., of Birmingham.
To be seen at work at the Gas-Works, Birkenhead.
Cause of removal to make room for extensions.
To be sold a bargain, taken down, and re-erected ready for work.
For particulars, apply to Messrs. ASHMORE AND WHILE, STOCKTON-ON-TEES, or to view to Mr. CALLOW, Gas Engineer, BIRKENHEAD.

Now ready, price One Shilling, No. 8 (to be continued Monthly) of

A TREATISE ON THE SCIENCE & PRACTICE
OF THE
Manufacture and Distribution
OF
COAL GAS.

LONDON: WILLIAM B. KING, 11, BOLT COURT, FLEET STREET,
OR OF ANY BOOKSELLER IN TOWN OR COUNTRY.

For the convenience of persons resident in remote districts, arrangements have been made by the Publisher to forward the "Treatise" by Post, securely packed, at the cost of 1s. 2d. Monthly, or 7s. for the Half Year.

Just Published, Price 2s. 6d.,

COMMON SENSE FOR GAS USERS,

Being a Catechism of Gas Lighting for Householders, Gas-Fitters, Architects, Engineers, Millowners, &c.

By ROBERT WILSON, C.E.

CROSBY, LOCKWOOD & CO., 7, STATIONERS HALL COURT, E.C.

Now ready.

THE GAS & WATER COMPANIES DIRECTORY
FOR THE YEAR 1877,

EDITED BY
CHARLES W. HASTINGS,
8, BUCKINGHAM STREET, ADELPHI, LONDON, W.C.
THIS WORK IS UNDER THE PATRONAGE OF ALL THE LEADING GAS & WATER ENGINEERS AND SECRETARIES OF THE METROPOLITAN & PROVINCIAL COMPANIES.
Price 5s. in Cloth Covers; by post, 5s. 2d. | Price 3s. 6d. in Paper Covers; by post, 3s. 8d.
PUBLISHED BY MESSRS. MARCUS WARD & CO., OF LONDON AND BELFAST.

Just Published, price 10s. 6d.,

AN ANALYSIS OF THE METROPOLITAN GAS COMPANIES ACCOUNTS
FOR 1876,
(In continuation of the Seven previous Years, 1869–1875,)
COMPILED AND ARRANGED BY JOHN FIELD,
MANY YEARS ACCOUNTANT TO THE LATE IMPERIAL GAS COMPANY.

By the same Author,

A COMPARATIVE AVERAGE ACCOUNT BOOK,
FOR THE ENTRY OF GAS COMPANIES ACCOUNTS FOR SERIES OF YEARS.
Price, for Half Yearly and Yearly Comparison, Foolscap Size, 21s.; Quarto, 12s. 6d.; for Yearly Comparison only, 8s. 6d.

To be had of W. B. KING, "Journal of Gas Lighting," 11, BOLT COURT, FLEET STREET, E.C.;
OR OF
EDEN FISHER & CO., Stationers and Engravers, 50, LOMBARD STREET, LONDON, E.C.

GAS PURIFICATION.

BAILES & HALLSWORTH,
CONTRACTORS FOR THE
PURIFICATION OF COAL GAS,
BY THEIR
PATENT OXIDE OF IRON COMPOUND.

The material is in use at most of the principal Gas-Works in Yorkshire and elsewhere. It contains considerably less moisture than natural Oxide of Iron. It is much cheaper and more efficient as a purifying agent.
B. & H. are purchasers of Spent Oxide, or will take Spent in exchange for New Material.
FOR SAMPLES AND TERMS, ADDRESS—
BAILES & HALLSWORTH, COPPERAS WORKS, ARMLEY, LEEDS.

NOTICE OF REMOVAL.

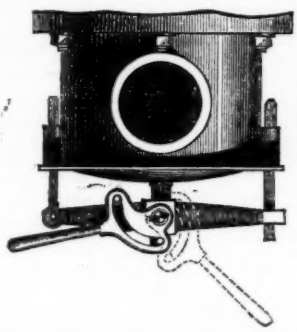
D. BRUCE PEEBLES & CO.
Beg to announce that they have REMOVED to their New Premises,
TAY WORKS, BONNINGTON, EDINBURGH,
To which all communications should now be addressed.
May 30, 1877.

JOHN HALL AND CO., STOURBRIDGE,

Manufacturers of FIRE-BRICKS, LUMPS, TILES,

AND EVERY DESCRIPTION OF FIRE-CLAY GOODS.

N.B.—A Stock of 15 and 16 in. CIRCULAR RETORTS always on hand. Other kinds made to order on short Notice.



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PATENT

RETORT-LID FASTENINGS

Have now stood the test of experience, and have been found one of the greatest improvements in retort-house appliances yet invented. All who desire security and economy should give them a trial.

Prices and further particulars will be given on application to

J. STORER,

GAS-WORKS, STAFFORD.

GEORGE ANDERSON,

GAS AND CONSULTING ENGINEER,

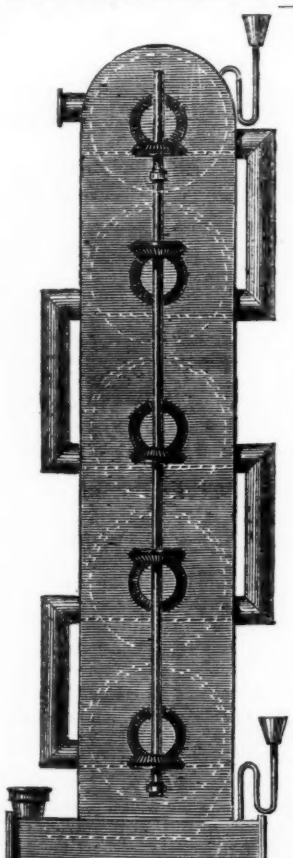
35A, GREAT GEORGE STREET,

WESTMINSTER, S.W.

ANDERSON'S

PATENT

COMBINED WASHER AND SCRUBBER.



TESTIMONY OF ITS ACTION.

The Gas-Works, St. Albans,
April 27, 1877.

DEAR SIR,

Your Brush Scrubber has been in action here for four months.

It removes the whole of the ammonia from the gas, so that it will not discolour moistened turmeric paper.

The brushes cause no appreciable increase of pressure, and there is no repumping of liquor. Clear water run in at top, issues from the bottom fit to proceed to the sulphate-house.

It performs its work more efficiently than the tower scrubber I have, while only about half the height, and not one-fourth its weight or capacity.

My purifiers also last much longer before they are foul than they did previously.

I am, yours truly,

A. F. PHILLIPS.

G. Anderson, Esq.,
35*a*, Great George Street, S.W.

PATENTEE and MANUFACTURER of the following Inventions:—

RETORT SETTINGS—giving great Economy of Fuel.

STEAM-ENGINES and EXHAUSTERS, FOUR-WAY VALVES.

FUEL-MACHINE, for Compressing Breeze and Tar.

N.B.—Pamphlet, with Eighteen Illustrations and Letterpress on the Construction of Gas-Works, post free, 2s. 6d.

PRICES AND ALL PARTICULARS TO BE HAD OF THE PATENTEE,

35a, GREAT GEORGE STREET, WESTMINSTER, S.W.

In the Press, and will be shortly published, price 5s., by post 5s. 3d., cloth, 8vo., gilt lettered,

SULPHUR COMPOUNDS IN GAS.

A full Report of the Evidence given before the Select Committee of the House of Commons on the Bills of The Gaslight and Coke Company and the Crystal Palace District Gas Company in the present Session.

As the number of Copies printed is very limited, early application to the Publisher is necessary, to prevent disappointment.

LONDON:

WILLIAM B. KING, 11, BOLT COURT, FLEET ST.

GAS-WORKS TO LET.

TENDERS are invited for a Lease of the Lampeter Gas-Works for a term of years.

Particulars may be obtained on application to Mr. DAVID LLOYD, Solicitor, LAMPETER.

AMMONIACAL LIQUOR AND TAR.

THE Directors of the Peterborough Gas Company invite TENDERS for the purchase of the AMMONIACAL LIQUOR and surplus TAR produced at their Works for a period of one year, commencing with July 1, 1877.

Tenders to be sent in, addressed to the Manager, Gas-Works, Peterborough, on or before the 10th of July next.

By order of the Directors,

JNO. GRAVES, Secretary.

Peterborough, June 19, 1877.

TO TAR DISTILLERS.

THE Directors of the Dover Gaslight Company are prepared to receive TENDERS for the purchase of the TAR produced at the Gas-Works, Dover.

Tenders to be sent in before Saturday, the 21st of July inst.

For information as to terms and conditions, apply to the undersigned.

R. H. JONES, General Manager.

Dover, July 2, 1877.

TO TAR DISTILLERS, &c.

THE Directors of the Kingston-upon- Thames Gas Company are prepared to receive TENDERS for the surplus TAR produced at their works at Kingston, from the date hereof to June 30, 1878. Quantity about 80,000 gallons, more or less. Tenders to be at per gallon, f.o.b. the Contractor's barge at Kingston.

Further particulars may be obtained from Mr. Packham, Manager, at the Works, where a copy of contract may be seen.

Tenders to be sent to Mr. W. A. Fricker, Secretary, Gas Offices, Church Street, Kingston, on or before the 31st day of July, endorsed "Tender for Tar."

The Company do not pledge themselves to accept the highest or any tender.

By order,

W. A. FRICKER, Secretary.

Gas Offices, Kingston, June 30, 1877.

BOROUGH OF WIGAN.

TENDERS FOR GAS MAINS.

THE Gas Committee of the Corporation are prepared to receive TENDERS for the supply of the following PIPES—viz., 2000 yards of 4-inch and 1500 yards of 3-in. The same to be coated with Dr. Angus Smith's patent preparation, and delivered free at the Gas-Works, Chapel Lane, Wigan.

Further particulars can be obtained from Mr. J. G. Hawkins, the Engineer, to whom sealed tenders must be sent not later than the 17th inst., endorsed "Tender for Gas-Mains."

The lowest tender not necessarily accepted.

MASKELL W. PEACE, Town-Clerk.

July 6, 1877.

THE BLAENAU FESTINIOG GAS COMPANY, LIMITED.

GASHOLDER.

THE Directors of this Company are prepared to receive TENDERS for a GASHOLDER, 30 ft. diameter, 10 ft. deep, put up at the Works, and complete with columns, wheels, chains, weights; also inlet and outlet pipes, valves, and connecting-pipes, inlet and outlet of present gasholder.

Any further information may be obtained on application to the Secretary.

Tenders are to be sent in on or before the 18th day of July next, endorsed "Tender for Gasholder," and addressed to the Secretary.

The Directors do not bind themselves to accept the lowest or any tender.

J. CADWALADR, Fourcrosses, R.S.O., *Vid* Carnarvon.

June 26, 1877.

NOTICE.

MESSRS. THOMAS DOCWRA & SON, Contractors, Balls Pond Road, hereby give notice that they have no business connexion with any other person of the same name.

TO GAS COMPANIES.

WE beg to call attention to our special STEATITE BURNERS for Street Lamps. Sample gross 8s. Quotations for quantities.

Messrs. TINDALL AND TELLING, Gas Apparatus Works, 74, Wynford Road, Fenton Street, LONDON, N.

TO INVENTORS AND PATENTEES.

MR. W. H. BENNETT, having had considerable experience in matters connected with Gas, Water, and Sanitary Improvement, begs to say that he continues to assist Inventors in the perfection of their designs, and to obtain for them PROVISIONAL PROTECTION, whereby their invention may be secured for Six Months; or LETTERS PATENT, which are granted for Fourteen Years.

Information as to cost, &c., supplied gratuitously upon application to the Advertiser, 32, Great George Street, WESTMINSTER.

BOROUGH OF ROTHERHAM.

TENDERS FOR GAS COAL.

THE Rotherham Corporation invite TENDERS for the delivery at Rotherham, in monthly quantities from the 1st of September next, of from 6000 to 8000 Tons of best GAS COAL.

The Coal to be 21 cwt. to the ton, well screened, to contain sparingly of sulphur, and be as free as possible from smudge, shale, bats, bind, or any other impurity.

Further particulars and monthly quantities can be obtained on application to the Manager, Gas-Works, Rotherham, or at the Gas Offices of the Corporation.

Tenders to be sent in to me, endorsed "Tender for Gas Coal," on or before the 21st of July inst.

The Corporation do not bind themselves to accept the lowest or any tender.

By order,
W. WHITFIELD, Town-Clerk.

Corporation Offices, Rotherham, July 6, 1877.

CONTRACT FOR GAS COAL.

THE Directors of the Alton Gas and Coke Company invite TENDERS for the supply of 750 Tons of good screened GAS COAL, to be delivered free at the Alton Station, South-Western Railway, as follows:—

200 Tons	August,	1877
200 ,, ...	November,	1877
200 ,, ...	January,	1878
150 ,, ...	March,	1878

The Coal to be of good quality, and free from bats, bind, pyrites, and other refuse.

Terms of payment net cash at the end of the month.

Tenders to be sent in by Monday, July 16, 1877, stating kind of Coal, and from what district and pits obtained.

The Directors do not bind themselves to accept the lowest or any tender.

R. LUCAS, Secretary, *pro tem.*

July 2, 1877.

PAMPHLET ON GAS.

COOKING AND HEATING.

HINTS ON GAS-BURNERS, &c.

For GAS COMPANIES to distribute to their Gas Consumers.

Specimen Copy by post Threepence, from the Author,

MAGNUS OHREN, Gas-Works, Sydenham, S.E.

T. NEWBIGGING,

CONSULTING GAS ENGINEER,

5, NORFOLK STREET, MANCHESTER.

HENRY LYON,

ENGINEER,

AND

CONSULTING GAS ENGINEER,

BARTON HOUSE, opposite BARTON ARCADE, DEANSGATE, MANCHESTER.

ALFRED LASS,

SPECIAL ACCOUNTANT FOR GAS COMPANIES,

30, GRACECHURCH STREET, LONDON.

Accounts analyzed and Statistics Prepared for Parliamentary Proceedings, Arbitrations, &c.

The Forms of Account, which have been specially designed by A. L. to meet the requirements of the Gas-Works Clauses Amendment Act, 1871, are now in use by many Gas Companies, and have been universally approved.

The above forms are registered.

Water Companies Accounts also prepared and adjusted.

CONSULTATIONS.

PATRONIZED BY THE ROYAL ARSENAL, WOOLWICH.

FERGUSON, Builder and Contractor. Kite method of Repairing Church Spires and High Chimneys. Chimneys straightened, pointed, and hooped. Old Chimneys pulled down by a process requiring no scaffolding or stoppage of work, by competent workmen, under personal supervision. For Lightning Conductors—cheapness and method of fixing—apply to C. R. FERGUSON, 12, Canal Road, MILE END.

YEO'S PATENT ENGINE PACKING.

BY HER MAJESTY'S ROYAL LETTERS PATENT.

No. 8, Self-Lubricating Packing, any size, 1s. 8d. per lb. This Packing supersedes all other kinds for High and Low Pressure Steam and other Pumps. No. 7, 1s. per lb. No. 5, Self-Lubricating Double-Twisted Soft Laid Cotton Packing, 1s. 8d. per lb. No. 2, Cotton and Soapstone, 1s. per lb. No. 6, Canvas Rope, with India-rubber Core, 1s. 8d. per lb. Canvas made from all Long Flax. Any Quantity can be forwarded from 1 lb. upwards, and carriage paid on ¼ cwt. and upwards to any Railway Station in the Kingdom. Tarred and White Yarn for Pipe-Joints, Torch Yarn, Coke Sacks, Fall Ropes, Cotton Waste, &c., at various prices, according to quality.

E. YEO, NEWTON ABBOT, DEVONSHIRE.

ADDISON POTTER,

WILLINGTON QUAY,
NEAR NEWCASTLE-UPON-TYNE,
Manufacturer of

CLAY RETORTS, FIRE-BRICKS, AND EVERY DESCRIPTION OF FIRE-CLAY GOODS

THOMAS CARR & SON,

MANUFACTURERS OF

FIRE-BRICKS, LUMPS, TILES, RETORTS,

&c., &c.,

SCOTSWOOD FIRE-BRICK WORKS,
SCOTSWOOD-ON-TYNE.

SAM. CUTLER & SONS,

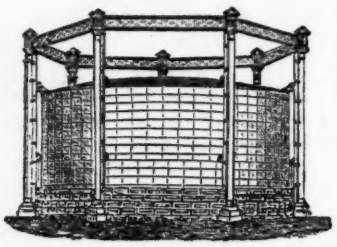
CONTRACTING GAS ENGINEERS,

GASHOLDER & GENERAL GAS APPARATUS MAKERS,

MANUFACTURERS OF

BOILERS, IRON ROOFING, IRON BRIDGES,

AND GENERAL IRONWORK.



S. C. AND SONS undertake Contracts of any magnitude for the **Erection of new and Remodelling of existing Gas-Works**, for **Gasholders, Cast and Wrought Iron Tanks, Iron Roofs**, and every description of **Apparatus** for the Manufacture and Distribution of Gas.

Special attention is invited to their **"Improved Condenser,"** which is very effective, and much approved; also to their patterns of **Annular** and other **Condensers, Scrubbers,** and **Purifiers,** of all sizes, which they arrange either with **Centre** or Ordinary **Slide Valves.**

WORKS FOR THE SUPPLY OF

VILLAGES, MANSIONS. FACTORIES, &c.

S. C. AND SONS undertake the **Supply** and **Laying** of **Mains** for **Gas and Water,** and supply all Castings, Connexions, and Fittings for Retort-House, Works generally, and for Streets. They also supply **Valves** of all descriptions, Iron and Clay Retorts, Hotpressed Retort-Lids, Steel Charging-Scoops of improved make, for which they have special machinery, Improved Coke and Coal Barrows, Cross-Bars and Screws, Bolts and Nuts, Furnace and Stoking Tools, Iron and Wood Purifier-Sieves, Lead, Yarn, Borings, &c., including every requisite whatsoever for a Gas-Work, a well-assorted stock being kept of those goods most in request.

SOLE MAKERS OF BRETT'S PATENT COKE BARROW.

Experienced Retort Setters sent to any part of the Kingdom.

Address: **PROVIDENCE IRON-WORKS, MILLWALL, LONDON.**

J. & J. BRADDOCK,

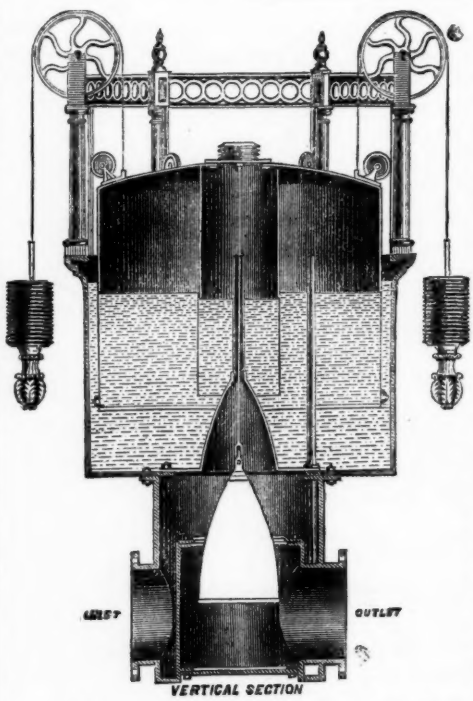
GLOBE METER-WORKS,

OLDHAM,

Beg to submit to Gas Engineers their

PATENT COMPENSATING GAS GOVERNOR,

Which is designed to give an uniform pressure at the Outlet to the Main at all draughts up to the full quantities which the Governors are made to control, such outlet pressure being less than the initial pressure.



VERTICAL SECTION

The uniformity of pressure is obtained by introducing a compensating chamber into the Bell or Holder of the Governor, which compensator is of the same area as the valve, both of which are operated on by the initial pressure, thereby placing the valve in equilibrium, no matter what the initial pressure may be. The action on the Bell is by the Gas passing along a pipe from the outlet, and the pressure is regulated by weights in connexion with the Bell as required.

From the sectional elevation attached hereto, it will be seen that only the Gas required to operate the Bell comes in contact with the water of the tank, which water will remain comparatively sweet and free from odour. That in case of accident to the Bell, no more Gas can escape than would pass up the pipe covering the valve-rod and Bell supply-pipe.

These Governors have been made and sent out of various sizes for from 2 to 24-inch Mains, and give most satisfactory results.

They can be made with Float in the Bell, or counterpoise as per section.

THE THAMES BANK IRON COMPANY,

(Successors to LYNCH WHITE,)

SUPPLY FROM STOCK

CAST-IRON RETORTS, SOCKET-PIPES for GAS or WATER PURPOSES, FLANGE-PIPES for STEAM, RAIN-WATER PIPES and GUTTERS, HOT-WATER PIPES and BOILERS, and all requisite Connexions for same; also LAMP-COLUMNS, LAMPS, WROUGHT FRAMES, WROUGHT-IRON TUBING, &c., &c.

All kinds of Gas-Works Apparatus and General Castings made to Pattern or Drawing.

ADDRESS—

OLD BARGE WHARF, UPPER GROUND STREET, LONDON, S.E.

B. GIBBONS, Jun.,

DIBDALE FIRE-CLAY, BRICK, AND GAS-RETORT WORKS,

STOURBRIDGE (Established 1834),

MANUFACTURER OF EVERY DESCRIPTION OF

Burs, Lumps, Stays, Shields & other Bricks, & Gas-Retorts.

A LARGE QUANTITY OF RETORTS ALWAYS IN STOCK.

Circular . 14 in., 15 in., 16 in., 18 in.
Ovals . . 17 in. × 14 in., 17 in. × 15 in., 20 in. × 15 in., 21 in. × 15 in., &c.
D's. . . { 14 in. × 14 in., 15 in. × 12 in., 15 in. × 13 in., 17 in. × 14 in., 18 in. × 13 in.
{ 18 in. × 15 in., 20 in. × 16 in., 22 in. × 14 in., 24 in. × 14 in., 24 in. × 15 in., &c.

Special attention given to the execution of Export Orders.

GEORGE ORME & CO.,

ATLAS METER-WORKS, OLDHAM,

MANUFACTURERS OF

WET AND DRY GAS-METERS,

STATION-METERS, GOVERNORS,

PRESSURE AND EXHAUST REGISTERS,

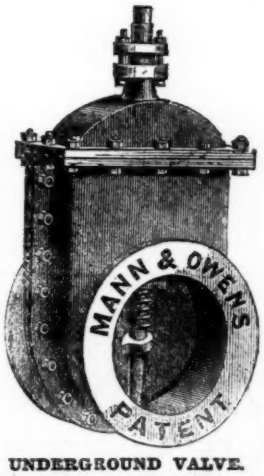
LAMP-METERS IN CAST-IRON BOXES,

And every Description of Gas Apparatus.

MANN & OWENS' PATENT GAS-VALVE.

VALVE, with Indicator for Above Ground.

EVERY VALVE WARRANTED TO BE PERFECTLY SOUND AND GAS-TIGHT.



UNDERGROUND VALVE.

The advantages of this Patent Valve over all others yet introduced are, that it is always as tight as the best wedge or spring valve, without the possibility of setting fast or becoming suddenly leaky. The surfaces not being in contact during the operation of opening or closing, leakage through wear and tear is avoided.

The Gas Engineer will not fail to see the importance of such a valve in connexion with his purifying apparatus, particularly in the case of large sizes.

The slide being operated either by a screw and nut, or by a pinion and rack, a cam bearing upon a plane, cast on the back of the Valve, forces it against the face, and renders the escape of gas an impossibility. By a slight turn of the pinion or screw, the slide is released, and brought away from the face, by which means friction is avoided, and the only force required to open the Valve is that due to its own weight.

SOLE MANUFACTURERS:

S. OWENS AND CO.,

HYDRAULIC AND GENERAL ENGINEERS,

WHITEFRIARS STREET, LONDON, E.C.

PRICES, SIZES, AND FULL PARTICULARS ON APPLICATION.

CATHELS'S Patent Gas-Washer is an excellent cleanser of gas from tar, ammonia, sulphur, and carbonic acid, reducing the cost of subsequent purification 30 to 50 per cent. Needs no motive power or attention beyond drawing off and recharging as required. Has no moving parts or complications to get out of order. Is of moderate cost, and is practically indestructible.

Application to be made to the MANUFACTURERS, the Horseley Company, Tipton, STAFFORDSHIRE.

BIRTLEY IRON WORKS,

CHESTER-LE-STREET,

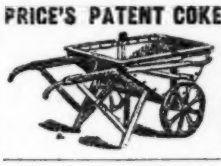
DURHAM.

Manufactory for every description of Casting and Machinery for Gas-Works and Water-Works.

Warehouse in London for Cast-Iron Pipes and Connexions of all sizes and in any quantity, Scott's Wharf, Bankside, Southwark.

Agent in London, Mr. J. MANWARING, 101 Cannon Street, E.C.

PRICE'S PATENT COKE & COAL BARROW



effecting a great saving of time, labour, and expense.

For particulars, price, &c., apply to Mr. E. PRICE, Inventor and Patentee, Gas-Works, Hampton Wick, MIDDLESEX.

WILSON'S

PATENT SAFETY PRESSURELESS

AUTOMATIC DIP-PIPES,

Fixed or moveable, adapted to works of any size, without other alteration than removal of existing Dips.

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BOUCK & CO., LIMITED,

TAR DISTILLERS & MANUFACTURING CHEMISTS,

MILES PLATTING, MANCHESTER.

BUYERS OF COAL TAR,

And Crude Products therefrom,

AMMONIACAL LIQUOR, &c.

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WORKS:

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TORBAY IRON PAINTS.

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These Paints have been for many years extensively used in Her Majesty's Royal Dockyards, Woolwich Arsenal, the Shorncliffe and Curragh Camps, War Departments, and Colonies, and are largely supplied to Railway, Harbour, and GAS COMPANIES, Shipowners, Engineering Establishments, Railway Carriage and Wagon Works, and the Paint Trade generally. They are the BEST PROTECTORS of WOOD, CEMENT, and IRONWORK, even arresting corrosion after it has set in; and their base being oxide of iron, they are free from those properties which make lead paints so destructive to iron. They do not scale or blister, are not affected by great heat, and are the only Paints which will resist the effects of sulphuretted hydrogen. Their DURABILITY and covering properties have borne the test of A QUARTER OF A CENTURY'S PRACTICAL TRIAL.

The undermentioned colours—ground in best linseed oil, and requiring only to be thinned down for use in the ordinary way—are kept in stock:—

Torbay Brown.	Torbay Red.
Dart Green.	Slate.
Dart Yellow.	Buff.
Brixham Black.	Torbay Chocolate.
Light Blue.	Cream Colour.
Dart Brown.	Dart Umber.
Imperial Stone.	Light Stone.
Bronze Green.	Salmon Colour.
Navy Green.	Lead Colour.
Carriage Red.	Dark Stone.
Light Lead.	Crystal Palace Blue.
Light Green.	Iron Grey.

All other Colours made to order.

READY-MIXED PAINTS.

A great variety of Colours ready mixed for the brush are also always kept in Stock, in 3 lb., 7 lb., 14 lb., and 28 lb. cans.

Prices and Testimonials on application.

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CONSULTING GAS ENGINEER
AND
CANNEL COAL FACTOR,
30, St. Andrew Square, EDINBURGH.

Plans and Estimates furnished; Gas-Works, Apparatus, Pipes, Machinery, Fire Goods, &c., supplied, or Attested and Shipped for Exportation.
GAS-WORKS TAKEN ON LEASE.

Mr. ROMANS has for upwards of 30 years been practically engaged in the Manufacture of Gas, and has, by extensive experiments, ascertained that by JUDICIOUS INTERMIXTURE of the lighter with the heavier gases, much of the rich Hydrocarbons CAN BE SAVED, which otherwise ARE LOST, during the process of manufacture. He is therefore enabled to give advice to those who favour him with their orders for Cannel, as to the class which will secure for their standard of illuminating power the HIGHEST ADVANTAGEOUS RESULTS.

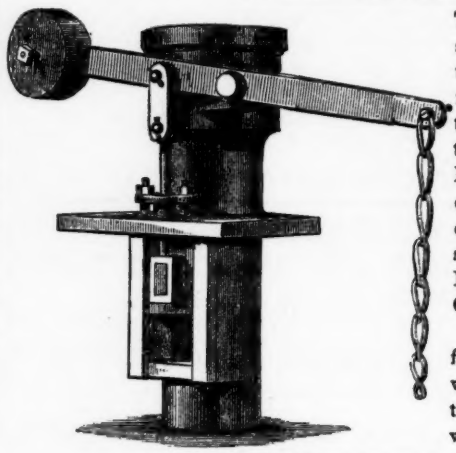
ANALYSIS AND PRICES FORWARDED ON APPLICATION.

HEBBURN MAIN GAS COALS.

T. Stone, Esq., of Weymouth, writes on Nov. 17, 1876: "I have used about 12,000 tons of this Coal, with, I think, the best possible results, although not always under the most favourable circumstances. My Coal account made up to Midsummer last showed a makeage of 10,534 cubic feet per ton of 14½-candle gas, and not a hundredweight of Cannel used. This statement would, I know, be incredible to many men, and may provoke the remark, 'How much of it is paid for?' For the gratification of such, I have to say that, of the above quantity, 9866 cubic feet per ton of Coal carbonized were brought to charge and duly paid for, with the exception of about 6s. per cent. for bad debts. The coke is of excellent quality. The above facts I hold to be a greater recommendation to your Coal than any words of mine could be."

THE TYNE COAL COMPANY, LIMITED, OWNERS.
W. RICHARDSON, Fitter,
29, QUAYSIDE, NEWCASTLE-ON-TYNE.

MOORE'S PATENT DIP-PIPE.



THE advantages of this Dip will be seen from the engraving. It is thoroughly effectual in its working, removing the whole of the pressure of the hydraulic main from the retort, thus causing a great saving in gas. It is very easy of manipulation, requiring little care and attention; it cannot get out of order, and, when shut, works as an ordinary Dip-Pipe. No accumulation of carbon in retort. Can be fixed to existing H-pipes.

In ordering the Dip, the distance from top side of hydraulic main to water-level should be stated; also the Dip at which it is required to work when the valve is shut.

PRICES—3-in., 35s.; 4-in., 42s.; 5-in., 48s.

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To whom all communications should be addressed.
MAKERS: THE COALBROOKDALE COMPANY, SHROPSHIRE.

THE WIGAN COAL & IRON COMPANY,
LIMITED.
DISTRICT OFFICE: 97, NEW STREET, BIRMINGHAM; AGENT: W. M'GOWAN;
Supply the Best Wigan Arley Mine Gas Coal, Gas Nuts, Gas Cannel, &c.
N.B.—The Wigan Coal and Iron Company, Limited, are exclusive owners of the well-known HAIGH HALL AND KIRKLESS HALL GAS COAL COLLIERIES.

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ROBT. DEMPSTER & SONS ELLAND
CIVIL ENGINEERS
DARE LUCEMA
AND PARLIAMENTARY APPLICATIONS CONDUCTED

ROBT. DEMPSTER & SONS,
GAS ENGINEERS, IRONFOUNDERS, AND CONTRACTORS,
ROSE MOUNT IRON-WORKS, ELLAND, YORKSHIRE,
MANUFACTURERS OF EVERY DESCRIPTION OF
GAS APPARATUS;
CONTRACTORS FOR THE
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Plans and Specifications Prepared, and Illustrated Catalogues forwarded on application.

IMPROVED
COMPENSATING GAS-METER.
HUNT'S PATENT.

This Meter supplies a want long felt, by putting an end to the loss sustained by Gas Companies through the overworking of their Meters.

COPIES OF REPORTS SENT ON APPLICATION.

MANUFACTURED BY
JOHN BENT & SON,
WET AND DRY GAS-METER AND GAS APPARATUS MANUFACTURERS,
BELL BARN ROAD, BIRMINGHAM.
Established 1830.

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GAS ENGINEERS & MANUFACTURERS,

IRONFOUNDERS AND CONTRACTORS,

GOWTS BRIDGE WORKS,

LINCOLN.

LONDON OFFICES: 1, WESTMINSTER CHAMBERS, S.W.

ESTIMATES FOR GAS-WORKS OF ANY SIZE.
REFERENCES TO 500 WORKS ALREADY ERECTED.

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JAMES OAKES & CO.,
ALFRETON IRON-WORKS, DERBYSHIRE,
AND
WENLOCK IRON WHARF, 21 & 22, WHARF ROAD, CITY ROAD, LONDON, N.,

Keep in London and at their works large stocks of PIPES and CONNEXIONS (1½ to 36 inches in diameter); also make and supply Retorts, Tanks, Columns, Girders, Special Castings required by Gas, Water, Railway, Telegraph, Chemical, Colliery, and other Companies.

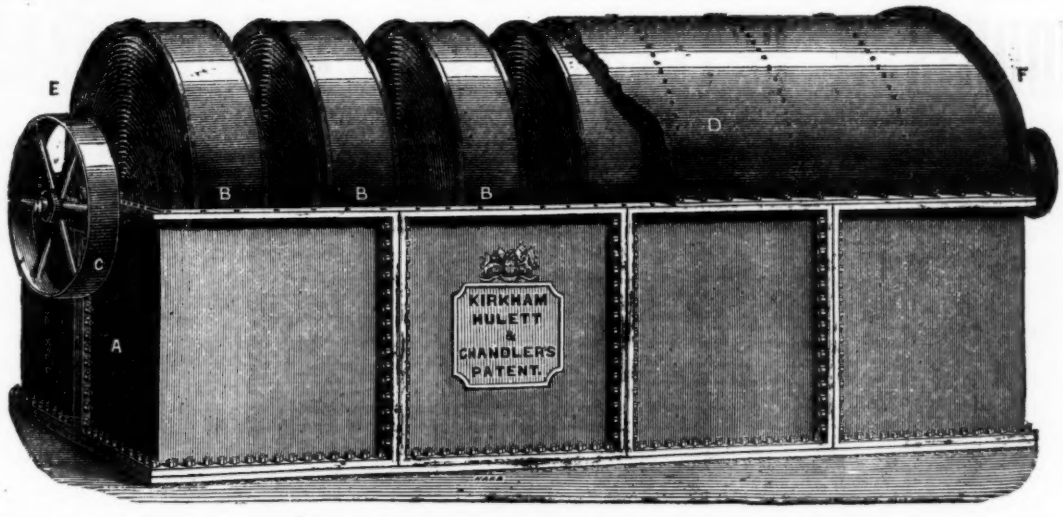
CHARLES HORSLEY, Agent.

CLOTH GAS-BAGS FOR MAINS,

As supplied to the Imperial, Chartered, and other London and Provincial Gas Companies. Bellows and Valves for inflating Well Dresses, Stokers Gloves, India-Rubber Suction and Delivery Hose, Gas-Tubing, Leather, India-Rubber, and Gutta-Percha Machine-Bands, Sheet and Washers, and Steam Joints.

T. BUGDEN, Manufacturer,
79, GOSWELL ROAD, LONDON, E.C.

STANDARD WASHER AND SCRUBBER.



The advantages of the Apparatus will doubtless be understood by those interested in gas manufacture.

The principal points of any Apparatus for the extraction of ammonia may be summarily stated as follows: —

1. **A large amount of Surface is desirable.**
2. **Such Surface should be always effectually Wetted.**
3. **The Surfaces or Scrubbing Material should cause no Pressure.**
4. **The Gas should meet various strength Liquors on its course.**
5. **However small the quantity of Water used, it ought to operate over the whole Surface.**
6. **Changing Scrubbing Material is both Objectionable and Expensive.**
7. **Economy both as to Space occupied and Cost of Apparatus is an important item.**

All these requisitions are supplied by the above Apparatus, of which the following is an explanation:—

A is a cast-iron tank, formed into several separate water-tight compartments.

B B B volutes of sheet iron fitted to the centre shaft, which is driven by the pulley, C, and causing the said volutes to revolve each in a separate compartment filled with water or other fluid.

D, the cover, has partitions fitted into it corresponding with those in the tank, sufficient space being left between the top of the partition in the tank and the lower edge of that in the cover, to allow the gas a free passage through the first volute to the second, and so on to the third, fourth, &c.

The action is as follows:—The crude gas entering at E is partly washed in the first compartment, which becomes 10 or 12 oz. liquor, or stronger if required, according to the quantity allowed to enter per ton; the gas then passes to the second, where the liquor is of a less strength; thence into a weaker liquor, as it passes from one compartment to the other, finishing at the last compartment or outlet, F, with clean water, which is constantly flowing and running over from one compartment to another, until it reaches the last space, from which it flows from the outlet-pipe into the well or tank ready for sale or removal.

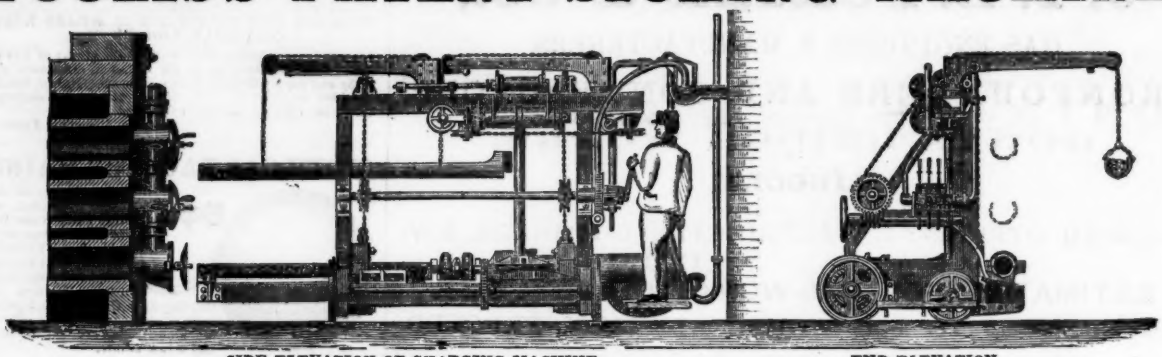
Taps are inserted in each compartment for the convenience of drawing liquor for testing, &c.

Applications as to Cost, &c., may be obtained of either

Mr. D. HULETT, 55 & 56, HIGH HOLBORN;
Messrs. KIRKHAM & HERSEY, GAS ENGINEERS, 21, ABINGDON STREET, WESTMINSTER;
Or Messrs. CHANDLER, 104, NEWINGTON CAUSEWAY.

Inquirers will please state their Maximum Day Make.

FOULIS'S PATENT STOKING MACHINE.

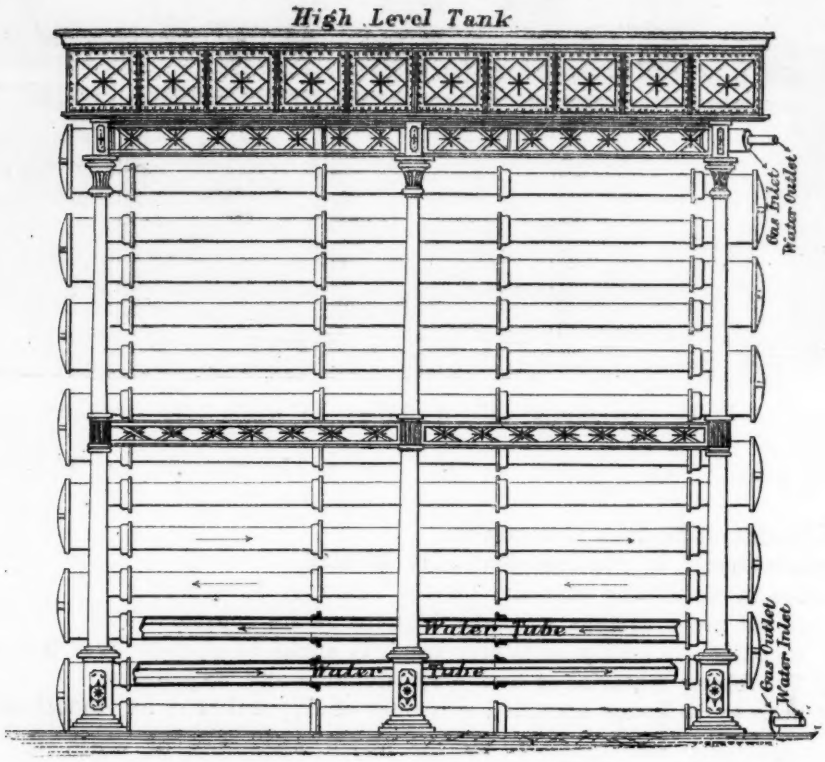


SIDE ELEVATION OF CHARGING MACHINE. END ELEVATION

(*The Drawing Machine will be Illustrated in next week's Advertisement.*)

Makers: TANGYE BROTHERS and HOLMAN, London and Birmingham; ADAM WOODWARD and SON, Manchester; ROBERT LAIDLAW and SON, Glasgow; MASCHINENBAU-ACTIEN-GESELLSCHAFT HUMBOLDT, Kalk bei Deutz:
Or all particulars may be had from JAMES WOTHERSPOON, 31, St. Vincent Place, Glasgow.

MORRIS & CUTLER'S PATENT CONDENSER.



The Condenser may consist of pipes arranged in tiers as shown, or in any other form most convenient to the site available, each tier being connected with special connexions, and containing within same either one or more coils of smaller pipe through which water is passed, being supplied from any convenient source of supply, the water passing in an opposite direction to the gas, so that the coldest water is at the gas outlet.

The power of the Condenser can be regulated precisely in proportion to the quantity of water allowed to pass through, which is not in any way contaminated, but simply heated by the hot gas, and advantage can be taken of its being at a high level to carry it to a high-level cistern, from whence it can be used for supply to boiler or any other purpose. (The Condenser itself may form the support for a high-level cistern as illustrated.) By an arrangement of valves the water may be shut off, and an air orifice opened, when air will pass through instead of water, or both air and water can be shut off. The power of the Condenser is, therefore, entirely under control.

The Condenser may be seen in operation at the Brentford Gas-Works.

For further Particulars, apply to

Mr. F. MORRIS, GAS-WORKS, BRENTFORD,

OR TO

S. CUTLER & SONS,

ENGINEERS, IRONFOUNDERS, AND CONTRACTORS FOR GAS AND WATER-WORKS,

MILLWALL, E.

GAS PURIFICATION & CHEMICAL Co., LIMITED,

(Successors to JOHN WILLIAM O'NEILL & CO.,)

Offices—PALMERSTON BUILDINGS, OLD BROAD STREET, LONDON, E.C.,

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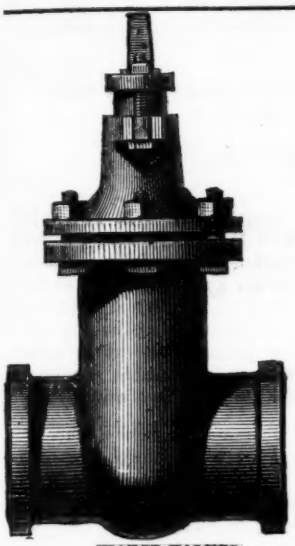
The superiority of the material supplied by this Company is generally recognized, and it is now in use in nearly all the London and most of the large Provincial Gas-Works.

JOHN WILLIAM O'NEILL, SAMUEL H. JOHNSON, } Joint Managing Directors.



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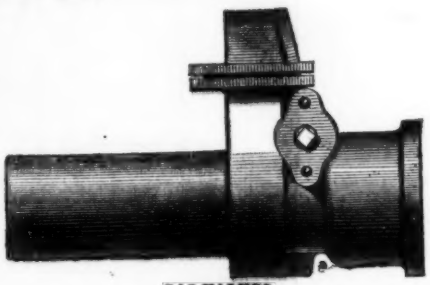
LONDON.

SCREW-COCKS, HYDRANTS,
SLUICES, PENSTOCKS,
And all other Machinery for
WORKS OF WATER SUPPLY, DRAINAGE AND IRRIGATION.



GAS-VALVES.
All Sizes, Flange and Socket, kept in Stock, tested to 100 feet head.

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IRON AND BRASS FOUNDERS,

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Glasgow Office: 54, ST. ENOCH'S SQUARE.

MANUFACTURERS OF ALL DESCRIPTIONS OF

HYDRAULIC MACHINERY,

INCLUDING

ACCUMULATORS, FORCE-PUMPS, CRANES, & LIFTS,

FOR

GAS-WORKS, WAREHOUSES, &c.

IMPROVED HYDRAULIC MACHINERY,

Specially Arranged for Lifting and Lowering Purifier-Covers, &c.

MAKERS OF

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PIPES FOR GAS AND WATER WORKS;

ROOFS, COLUMNS, AND GIRDERS.

DESIGNS AND ESTIMATES SUPPLIED ON APPLICATION.

C. & W. WALKER,
8, FINSBURY CIRCUS,
LONDON, E.C.

MANN & WALKERS' PATENT SCRUBBER.

By Letters Patent in Great Britain, Europe, and the United States of America.

By some important improvements recently patented, the purifying power of these Scrubbers has been much increased, and a stronger ammoniacal solution obtained, which is found to absorb a large portion of the carbonic acid contained in gas, effecting an important saving in money and labour in the lime purifiers, and where oxide only is used, the increase in the illuminating power of the gas obtained by these Scrubbers is shown in a remarkable degree, in consequence of the large quantity of carbonic acid removed from the gas.

It is to be particularly noted that the important results of these Scrubbers do not depend upon the machinery alone. The entire internal construction of the Scrubber bears an almost equally important part. For this reason, where it is desirable to convert existing Scrubbers, whose dimensions happen to be suitable, the work commences by ripping out the whole of the interior of the shell, and beginning the internal construction *de novo* from bottom to top.

They are, in all cases, constructed under guarantees to perfectly perform their work. They are now extensively used in the largest gas-works of London and the chief cities of Europe, the number in use exceeds **one hundred,** and their perfect efficiency and profit to a gas company have been fully established with every variety of coal used in Europe. References can be given to the largest gas-works in Europe.

By their use the department of purification from ammonia upon a gas-works is made complete, without the aid of prepared oxide of iron, chemicals in purifiers, or any other supplementary process, and the whole ammoniacal residual product contained in the coal is absorbed and obtained in the form most profitable to a gas company, while the requirements of all Acts of Parliament and of the Board of Trade, relating to incorporate gas companies, are satisfied.

Foul Gas, properly condensed, entering the inlet is, by once only passing through the Scrubber, completely purified from ammonia with regular certainty day by day, without any further trouble, or any other process, effected by a very small quantity of clear water let into the machinery room at the top of the Scrubber, which is discharged at the liquor outlet at the bottom, from Newcastle coal at about 18 to 20 ounces strength, from Yorkshire and other coals, generally from 25 to 30 ounces strength; while acidulated litmus or turmeric exposed at the Scrubber outlet will not show the slightest discoloration, and there is not a quarter of a grain of ammonia per 100 feet left unabsorbed.

They contain their own engine power, requiring only a small inappreciable quantity of steam from the gas-works boiler, and are then complete in themselves, ready for service.

Applications relating to dimensions and prices should be addressed to us, C. AND W. WALKER, 8, FINSBURY CIRCUS, LONDON, E.C., or to Mr. WILLIAM MANN, late Superintendent of the Chartered Gas-Works, BLACKFRIARS, LONDON; they should state approximately the largest make of gas in 24 hours on a winter's day, and the smallest make on a summer's day, to be purified.

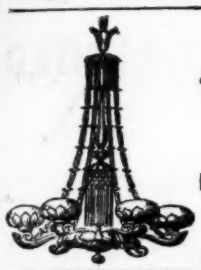

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TABLE GLASS OF ALL KINDS.

CHANDELIERS IN BRONZE AND ORMOLU. MODERATOR LAMPS.

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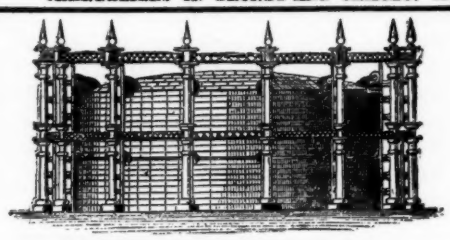

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GAS APPARATUS OF EVERY DESCRIPTION,

Including Improved

Retort-Lids, Boilers, Cast and Wrought Iron Tanks, Iron Roofing, Bridges, Girders,

And GENERAL IRONWORK.

N.B.—Estimates for all Gas Plant and Remodelling supplied on application.

LESMAHAGOW CANNEL COAL.

FERRAND DAVIES,

148, GRESHAM HOUSE, OLD BROAD STREET, LONDON, E.C.,

SOLE AGENT FOR

THOMAS BARR'S LESMAHAGOW MAIN CANNEL.

Quotation and Analysis forwarded on application.

G. J. EVESON,

GAS COAL AND CANNEL FACTOR,

Has on offer, in quantities to suit purchasers, Best Wigan Arley Mine, Orrell Screened and Unscreened Gas Coal and Nuts; Best Yorkshire, Real Old Silkstone, Derbyshire, and North Staffordshire Screened and Unscreened Gas Coal and Nuts; also Best Lancashire, Yorkshire, Derbyshire, and other Cannel, as supplied to some of the principal Gas Companies in England, to whom references are permitted.

Analysis and Prices forwarded on application to

HEAD OFFICES, STOURBRIDGE.

N.B.—Gas Managers will oblige by advising when they will be prepared to receive Tenders.

STOURBRIDGE FIRE-BRICKS, RETORTS, CLAY, &c.

ROBERT MARSHALL,

CANNEL COAL MERCHANT,

173, ST. VINCENT STREET, GLASGOW.

SHOTT'S BOGHEAD.

LOTHIAN'S CANNEL

Yields 12,500 cubic feet of 34-candle gas per ton, and 9 cwts. of excellent coke, containing only 4 per cent. of ash.

MUIRKIRK, No. 1, CANNEL

Yields 12,160 cubic feet of 32·5-candle gas per ton, and 10 cwts. of excellent coke, containing only 5 per cent. of ash.

OLD WEMYSS CANNEL

Yields 13,320 cubic feet of 32·5-candle gas per ton.

Prices and full Analyses on application.

GAS COAL.

POPE & PEARSON, LIMITED, have now the authority of several of the most eminent Gas Engineers of London in stating that their Coal yields *in practical working over* 10,000 *cubic feet of gas, with an illuminating power of* 16 *candles;* or by the standard burners now used by the London Gas Companies, an illuminating power equal to 17½ candles.

One ton yields 12½ cwt. of good coke. This Coal can be shipped from Hull, Goole, Liverpool, Morecambe, and Barrow.

For further particulars, apply to POPE AND PEARSON, LIMITED, West Riding and Silkstone Collieries, near LEEDS.

SCOTCH CANNEL COALS.

The Subscriber is prepared to contract for the supply of all the principal SCOTCH CANNEL COALS. Prices and Analyses of the various Coals will be forwarded on application.

JAMES M'KELVIE,

CANNEL COAL MERCHANT,

HAYMARKET, EDINBURGH.

Established 1840.

WILSON CARTER & PEARSON,

GAS COAL AND CANNEL FACTORS,

Supply to any Railway Station or export Best Wigan Arley Gas Coal and Nuts; best qualities of the Derbyshire, Yorkshire, and North Staffordshire Gas Coals and Nuts; also the best descriptions of Lancashire, Welsh, Scotch, and other Cannel.

Messrs. WILSON CARTER & PEARSON, being contractors to several of the principal Gas Companies in the Midland Counties, have pleasure in being enabled to give them as references.

Chief Offices: Temple Buildings, 50, New Street, Birmingham.

London Offices: 6, Great Winchester St. Buildings, E.C.

GRIRDROD'S PATENT

PORTABLE PIPE SCREWING MACHINE,

For 1 in., 1¼ in., 1½ in., and 2 in. Gas Threads, complete £7 10s.

In use at the chief gas-works, and giving great satisfaction.

For other useful goods, see Bailey's "Illustrated Inventions," post free 3s. 6d.; gratis to ledger customers.

W. H. BAILEY & CO.,

Brassfounders, Gauge Injector and Tool Makers,

ALBION WORKS, SALFORD, LANCASHIRE.

ALBERT GAS COAL.

THE DERBYSHIRE

SILKSTONE COAL COMPANY,

LIMITED,

CAN OFFER A

GAS COAL

Of superior quality, delivered in trucks at any Railway Station in England, or shipped on board at Hull, Grimsby Docks, or Barrow-in-Furness.

Purified gas per ton of coal in cubic feet (average)	10,262
Illuminating power in candles	15·86
Weight of coke in lbs. per ton of coal	1,502

ANALYSIS AND PRICES ON APPLICATION TO

Mr. EDMUND TAYLOR, Secretary,

ALBERT COLLIERY, NEWBOLD, NEAR CHESTERFIELD.

THE SILKSTONE & DODWORTH COAL & IRON COMPANY, LIMITED,

DODWORTH, BARNSLEY.

BENJAMIN WHITWORTH, Esq., M.P. . . . . Chairman.
Mr. RICHARD HARTLEY . . . . . Managing Director.

REAL OLD SILKSTONE GAS COAL.

JAMES PATERSON, Esq., Gas Engineer, of the Warrington Gas Company, reported, Aug. 10, 1875:—

"This Coal possesses remarkable qualities as a gas and coking coal, and appears SECOND TO NONE IN THE KINGDOM. It contains the large quantity of 699 lbs. of illuminating matter, and 1498 lbs. of coke to the ton, and produces 12,240 cubic feet of 16·66 candle gas."

The above Company are raising nearly a thousand tons of the Real Old Silkstone Gas Coal per working day.

PRICES QUOTED TO ANY RAILWAY STATION, OR F.O.B. HULL, GRIMSBY, GOOLE, KEADBY, LIVERPOOL, AND FLEETWOOD.

THE

WIGAN & WHISTON COAL COMPANY,

LIMITED,

(COLLIERIES—PRESCOT, NEAR LIVERPOOL)

Are now prepared to supply their

RUSHY PARK GAS COAL,

Either to Gas-Works in England or Wales, or for Shipment, at Runcorn, Garston, Birkenhead, or Liverpool.

This Coal is of superior quality, and yields in practical working over 10,000 cubic feet of Purified Gas per ton, with an Illuminating Power of 17½ candles.

One Ton of Coal yields 1441 lbs. of good Coke.

For prices, &c., apply either direct to the Colliery or to the Company's Office,

195, FALKNER STREET, LIVERPOOL.

SILKSTONE GAS COAL

AND

LANCASHIRE AND MIDLAND CANNEL.

EMOR G. WRIGLEY, Merchant,

Having made arrangements with four large Collieries for the exclusive sale of their GAS COAL and CANNEL, can offer to Gas Companies large quantities, for delivery over one or two years, at exceedingly low prices. His REAL OLD SILKSTONE GAS COAL will give, in regular work, 10,200 feet 16·6 candle gas and 13 cwt. superior coke; and a WIGAN CANNEL 11,375 feet 21·75 candle gas and 12 cwt. superior coke.

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1862.

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MADE ONLY BY

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CLASS II.

This Paint having been in general use over fifteen years (especially in some of the principal Gas-Works), and proved itself the best light-coloured Paint produced for resisting the influence of vitiated atmospheres, it is important that its qualities should be more widely known.

It is not discoloured like white lead in a sulphuretted atmosphere, nor washed off like white zinc; and its light colour reflecting heat, produces much less expansion of gas in holders painted with it than with dark colours, besides rendering them much more sightly. Its specific gravity is so much below white lead that the same weight will cover one-third more surface, while it is equal in body; and its price being about the same (30s. per cwt.), it is actually one-third cheaper. From experience, its manufacture is greatly improved, and it is quite suitable for all purposes in which white lead is employed.

The following Gas Companies in London have used the Paint for years—viz., The Gaslight and Coke, Imperial, Independent, City of London, Commercial, London, and Surrey Consumers.

N.B.—Antimony Paint, COVERING SO MUCH MORE WORK, costs about 20s. per cwt., as compared with White Lead at 30s. per cwt.; a similar economy arises from its use in Steam and Gas Joints, for which purpose it is superior to White Lead.

SPECIAL DRIERS FOR ANTIMONY PAINT SUPPLIED.

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A recent extensive development of the Collieries enables us to offer increased supplies.

JAS. PATERSON, Esq., of Warrington, after testing various qualities of our Coal, has sent the following testimony of their merits:—

Warrington Gaslight and Coke Company,
Offices, Mersey Street, Warrington, April 23, 1877.

Messrs. NEWTON, CHAMBERS, AND CO.,

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After carefully testing the various samples of Gas Coals sent from your Collieries for analysis, I have pleasure in reporting them as belonging to the highest class of Gas and Coking Coals.

The average of Nine samples gives a yield of 12,500 cubic feet of 15½ Candle Gas, being equivalent to 664 lbs. of sperm per ton, and 1420 lbs. of fixed carbon of a very superior quality. All the samples bear a close relation to each other in value.

Yours truly,

JAMES PATERSON.

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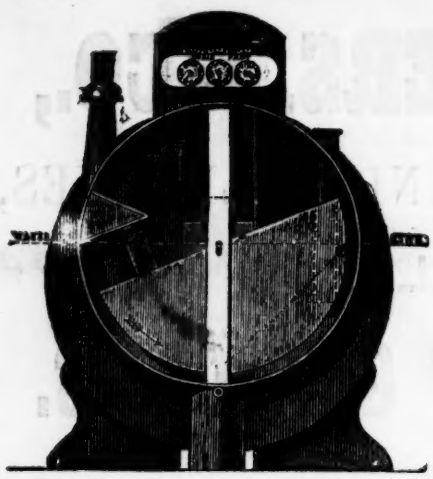

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Over 120,000 in action.

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In the above-named little Work will be found clear explanations of the usual methods by which the strength of Liquor is ascertained, an exposition of the imperfections of those methods, together with instructions for testing on an improved system, by which the total quantity of Ammonia in Gas Liquor may be determined with facility.

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Manufacturers of

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IMPROVED DRY GAS-METERS, in Cast-Iron or Tin-Plate Cases;

STATION-METERS, ALL SIZES, up to 15 feet Square, with PLANED JOINTS;

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July 2, 1877.

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